UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

HONOURS (Computer Science / IT)	APK CAMPUS
IT18X07 **OPTIMISATION** **EXAMINATION** **SSA** **MEMORANDUM**	
2020–12	

EXAMINER		**Prof. DA Coulter**	
EXTERNAL MODERATOR		**Dr GB O'Reilly (VAS-X / USC)**	
TIME	**2 HOURS**	**MARKS**	**100**

Please read the following instructions carefully

1. **You must complete this test yourself within the prescribed time limits.**
2. **You are bound by all university regulations please special note of those regarding assessment, plagiarism, and ethical conduct.**
3. **You must complete and submit the** `"Honesty Declaration : Online Assessment"` **document along with your submission to EVE. No submissions without an accompanying declaration will be marked.**
4. **You may submit scanned pages as per the instructions on EVE**
5. **Your answers to the question (in a single PDF format) together with the declaration must be submitted in a zip archive named in the following format.**
   `STUDENTNUMBER_SURNAME_INITIALS_SUBJECTCODE_ASSESSMENT`
   `e.g. 202012345_COULTER_DA_IT18X07_EXAM_SSA.zip`
6. **Additional time for submission is allowed for as per the posted deadlines on EVE.**
7. **No communication concerning this test is permissible during the assessment session except with Academy staff members.**

Question 1 – Evolutionary Algorithms – 30 marks

The US Robotics and Mechanical Arms corporation is in need of a motion planning software suit in order to control the movement of an industrial robotic arm. The arm is controlled by applying varying amounts of power for varying durations to a set of servomotors in sequence.

a)	You are to use a variation of the standard evolutionary approach to help plan the motion of the arm for an unchanging set of movements as part of an industrial process. The arm must avoid a set of immovable obstacles as part of its motion. The motion should be a short as possible and consume as little power as possible.
	• Discuss your approach in terms of the following (5 marks)
	  ○ Candidate solution representation Reasonable representation chosen which represents the action taken by each motor. For example a real valued vector with each element corresponding to a servermotor. Possibly a 2-tuple at each element one corresponding to power and one to power.
	  ○ Evolutionary operators and associated strategies. – Any reasonable Mutation, cross over, and selection operations based on the representation chosen previously.
	  ○ System parameters -Based on operators chosen previously eg. Mutation rate, population size, fitness thresholds
	  ○ Fitness evaluation. -Describe scoring number of movements, outcome, etc as weighted sum
	  ○ Stopping conditions – Stopping should be based on finding a valid solution of acceptable quality and not simply a fixed number of iterations
	• Provide a UML activity diagram for your customized algorithm (5 marks)
	  ○ Suitable states, activities, branches, conditions and transitions adapted from the pseudo code in the textbook to the problem.
		[10]

b)	The company has just made a deal with the leading cloud service provider Valdivian Web Services (VWS). How would you adapt your approach to work well in a cloud context? What would the impact be in terms of balancing exploration versus exploitation? • Islandic evolution – bias toward exploration	[5]

	• GAs lend themselves to parallel implementations (individuals do not have to "interact" directly).
	• The main categories of parallel implementations are as follows:
	  • Single population, master-slave GAs, where the evaluation of the fitness function is distributed over several processors.
	  • Single population, fine-grained GAs, where each individual is assigned to one processor and each processor to one individual. A small neighbourhood is defined for each individual (cpu), with selection and reproduction restricted to that neighbourhood.
	  • Multi-population or islandic GAs, where multiple populations evolve concurrently (each on its own cpu) and individuals "migrate" from time to time.
	• A good migration population policy is required, with the following components considered:
	  • A **communications topology**, which determines the migration paths between populations.
	  • A **migration rate**, which determines the frequency of migration.
	  • A **selection mechanism** to decide which individuals will migrate.
	  • A **replacement strategy** to decide which individuals if the destination island will be replaced by the new individual.	

c)	The robot arm is now equipped with rather poor-quality sensors. Due to ongoing internal reorganization of the factory floor the location of obstacles may change without warning. In addition, you are now required to avoid unnecessary wear and tear on the robot as well as limit the robots use of power. In addition, precise values for how much power a given movement will require are only roughly known. Provide a thorough description of the kind of problem domain you now face. • Constrained – Describe the penalty function or Uncostrained and justify why the fitness function is the objective function • Multi objective • Dynamic • Noisy	[5]
d)	The arm design is now on widely used and a great deal of telemetry is available for the arm's usage in real world environments. Management would like to write software which evolves functions describing the real-world usage of these arms. You may use either Genetic Programming or Gene Expression Programming to do so. Justify your selection of your chosen technique and detail what would need to be done in the context of this problem for your selected approach. Similar to main paper	[10]

Question 2 – Particle Swarm Optimisation

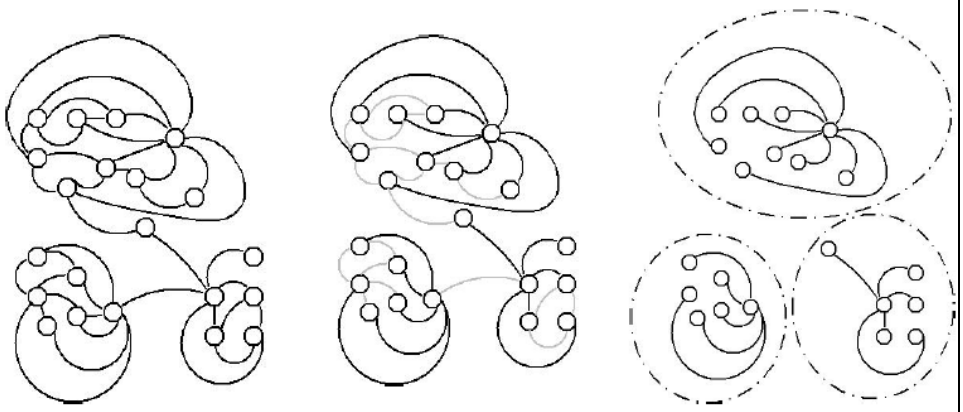
a)	In addition to telemetry data regarding robotic arm operation a great deal of information is being collected about the details of the environment within which the arms operate and whether or not they experienced a failure. These details include information regarding humidity, temperature, water coolant mineral hardness, power stability, air quality, etc. One of the other teams in the company, The Connectionist Intelligence Group, have created a black box neural network model of robotic arm failure which provides a probability that the arm will fail within when operated under a given set of conditions.	[10]

	This is useful but management would rather know what the best operating conditions are. They would like you to use one of the basic variants of PSO in order to explore this space.
	• Describe how you would implement such a system in detail in terms of:
	  ○ Problem representation -Each node in input layer corresponds to one element of particles position vector.
	  ○ Fitness evaluation -Send each element of current position as input to feed forward network. Result in output layer is the fitness value.
	  ○ Initialisation of the algorithm -Uniformly distribute participles. Velocity to 0
	  ○ Termination criteriaRather not fixed iterations, rather slope of global best, clustering of particles, lack of improvement in global best
	  ○ Social network structures -Any reasonable neighbourhood function.
	• Provide pseudocode for your version of the approach. Where you include mathematical expressions be sure to include a description of how this relates to your problem domain. (5 marks)
	Same approach as main paper.	

b)	Describe the parameters of your PSO system. As per main exam	[5]
c)	Discuss a couple of ways in which exploration vs exploitation can be controlled in your system and/or a few modifications to your system which will help do so. • Adjusting of control parameters, charged PSO, predator-prey, velocity clamping, inertia, annealing schedules, etc	[5]

d)	While the neural network based model of failure prediction works management isn't too pleased that no one can really explain **why** it works. It turns our that the problem of predicting failure is very highly dimensional. Researchers in the company have created simple, human understandable, models of product failure but these can only consider a few of the dimensions at a time.
	
	Describe how you can still explore the parameter space of these simple models collectively via a cooperative split particle swarm system. Pay special attention to the problem of fitness evaluation within this context.
	Cooperative Split Algorithm
	$K_1 = n_x \bmod K$;
	$K_2 = K - (n_x \bmod K)$;
	Create and initialise K_1 $\lceil n_x/K \rceil$-dimensional swarms;
	Create and initialise K_2 $\lfloor n_x/K \rfloor$-dimensional swarms;
	repeat
	  for *each sub-swarm* $S_k, k = 1, \ldots, K$ **do**
	  for *each particle* $i = 1, \ldots, S_k.n_s$ **do**
	  if $f(\mathbf{b}(k, S_k.\mathbf{x}_i)) < f(\mathbf{b}(k, S_k.\mathbf{y}_i))$ **then**
	  $S_k.\mathbf{y}_i = S_k.\mathbf{x}_i$;
	  end
	  if $f(\mathbf{b}(k, S_k.\mathbf{y}_i)) < f(\mathbf{b}(k, S_k.\hat{\mathbf{y}}_i))$ **then**
	  $S_k.\hat{\mathbf{y}}_i = S_k.\mathbf{y}_i$;
	  end
	  end
	  Apply velocity and positional updates;
	  end
	until *until stopping conditions are met*;
		[10]

Question 3 – Ant Colony Optimisation

a)	The robotic arm factory is itself being automated. As part of the process management would like you to design a way for small repair robots to be able to find their way to supply depots and broken machines as needed in a dynamically changing factory floor environment. They would like you to base this approach on the foraging behaviour of ants. Describe in detail how you would do so including details about environmental representation and inter-ant communication. Environment as grid or equivalent 2D lattice graph Machine as nest, supply depot as food source Some indication of how pheromone values can be represented Rest as per main, adapted for this problem domain	[10]
b)	Describe the parameters for your system in detail. As per main, adapted for this problem domain	[5]
c)	Productivity has dropped amongst the remaining human work force. HR believes the issues may be the formation of silos / cliques (groups of employees who communicate more with each other than with members outside their group). HR would like you to identify these groups by analysing the email communication patterns of employees via an ant-based system. • Employees are nodes in graph • Edges between employees who have communicated • Edges are weighted based on frequency of cumnmunication • Ants wander graph. Are more likely to select stronger edges. • Edges which are traversed are strengtehend those which are not are weakened. • When edge weights reach 0 they are removed and cannot be traversed • Clusters emerge in graphs 	[10]
d)	Having identified the workers who were most involved in the loss of productivity HR has given you access to their Personnel Database which contains information about each employee such as their psychological and physical profiles. They would like to see if there are any patterns in those employee profiles. That is, things that make them more similar to each other than to normal productive staff members. You have been asked to construct an ant based clustering approach to mining this data. As per main exam adapted to this problem domain	[5]

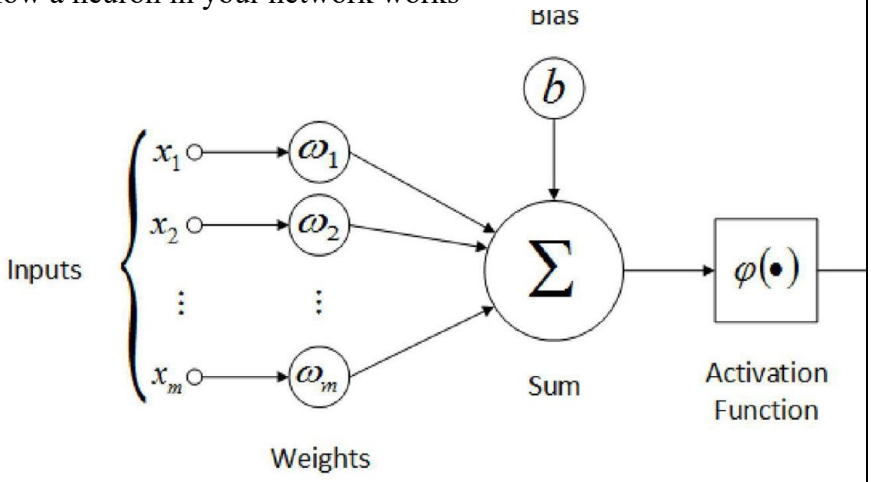
Question 4 – Hybrid / Connectionist / Additional approaches

a)	The head of the Connectionist Intelligence Group has resigned in a rage and deleted both the trained neural network weights for the product failure prediction model as	[10]

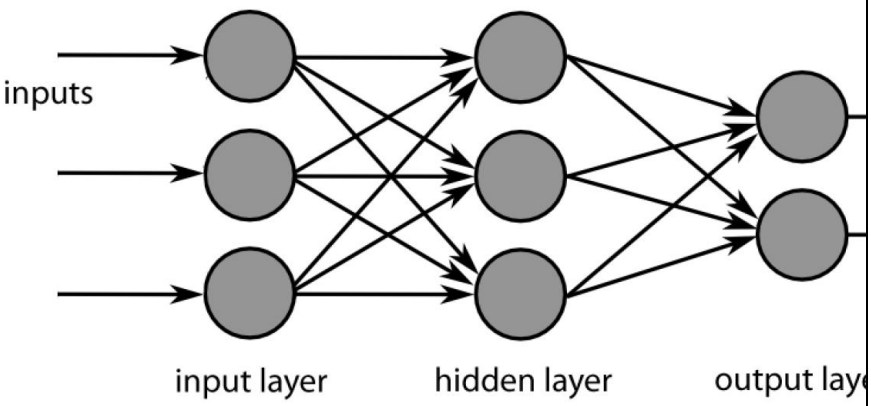
well as the source code for the system they developed. Due to the version control system being little more than an FTP server and a sense of optimism there is no hope of reconstructing that which was lost.

Management has tasked you with retraining the neural network using your choice of either an evolutionary or neural network-based approach. Describe in detail how you would do so in terms of the following (2 marks each):

- How a neuron in your network works



- How the neural network works (a multi-layer perceptron network)



- How you map the network onto your chosen approach
  Weights represent elements in real values genome or elements of particle position vector
- How you evaluate fitness
  Feed weights into input layer
- Any complexities which may arise as a result of your chosen approach
  Real value representation (evolutionary algorithm)
  High particle velocities (PSO)