Paper 2—Option B: Modelling and Simulation

SL/HL Core

Mathematical models are used to provide information to building designers.

B1(a) Identify two characteristics of a mathematical model,   [2 marks]

A mathematical model is a representation of a physical situation in the form of equations which abstracts the situation so that it can be manipulated more easily.

2

Any new building must be constructed to resist the force of a possible earthquake. The force (V) that the building must resist in order to prevent collapse, varies according to the following variables:

Variable	
Z	The Earthquake zone (1- 3) in which it is constructed
I	Importance of building according to its intended use (school, hospital etc.)
C	Structure index based on the dimensions, the weight and the shape of the building.
R	Flexibility of the building.

A simplified version of V can be calculated by the formula:

$V = (Z * I * C) / R,$

where Z and I are given and the values of C and R are obtained from published tables.

A building designer needs to be able to calculate the value of V for any one of a large number of buildings that is being designed. Z is fixed for all buildings; I, C and R can vary from building to building.

(b) Outline why the use of a spreadsheet is appropriate for this modelling task.   [2 marks]

A spreadsheet is appropriate because formulae be inserted easily and as values of W,C and R are changed during the planning, the value of V is always up-to-date.

2

(c) Construct a diagram to show the way in which data and calculations would be implemented in a spreadsheet.   [4 marks]

A	B	C	D	E
Earthquake zone (Z)	=1 or 2 or 3			
Force (V) =(ZIC)/R	Importance (I)	Weight (W)	Structure Index (C)	Flexibility (R)
= (B1*B4*C4*D4)/E4	Manually entered	Manually entered	Select value	Select material

Very clear and appropriate use of cell formulas, absolute and relative cell references.

4

(d) Outline how data from the look up tables could be input into the spreadsheet.   [4 marks]

The look up tables would need to be imported in a suitable format. This could be manually entered into the spreadsheet as different worksheets. Once the data was in the spreadsheet the choices could be presented as a drop down box for C and for R for each building. This would help prevent errors in manually inputting values from the look up tables.

4

Within a city in an earthquake zone there are many different designs of buildings. It is decided to test all buildings for their resistance to a possible earthquake in that zone.

e) Describe the data collection and data input needed to use the spreadsheet to test all buildings.

[6 marks]

Each building is specified by a row in the spreadsheet with a column added to identify and the relevant equations entered once.

The formulas can then be dragged down so that they are copied for the needed number of buildings, while the value for the earthquake zone stays constant.
The values for I would be entered manually for each building according to its use after being decided or calculated elsewhere,
The values for C and R could be selected from a drop down box, as the values for each building are entered the value of the force (V) will be updated and shown in the first column, giving the building designers the value of the force the building will be required to withstand.

6

B2. Despite many attempts the simulation of an earthquake by computer has proved inaccurate and planned buildings are tested by making a physical model and applying the relevant forces to see if it can withstand an earthquake in the given zone.

(a) Explain the relationship between simulation and mathematical modelling.   [2 marks]

A simulation uses a mathematical model by submitting it to changing variables to predict the behaviour of a system. The model may be static but the simulation is dynamic.

2

(b) With reference to a simulation with which you are familiar, explain the importance of accurate rules and data in a simulation.   [4 marks]

Before being constructed, electronic circuits will usually be simulated to check for correct operation of the circuit. At this stage it is possible for assumptions to be made about the characteristics of available components which will have a significant impact on the results. For example if a particular device is not available then a lower quality component may need to be substituted which could result in the overall circuit not performing as desired. If the simulation is run with incorrect assumptions then the final product may not perform as expected which will only be discovered after an expensive manufacturing process.

Well explained using banded response.

4

Simulation has proved successful in predicting weather patterns.

Describe the advantages and social consequences of using simulations in weather forecasting.   [4 marks]

Simulations tend to be seen as what will happen and are relied on to make decisions. If the simulation is inaccurate either from the use of an incorrect model or by applying the wrong values to the variables then the decisions could have serious social consequences. Some of these could be disastrous as in the construction of buildings as seen above, or long term weather simulations which do not predict global

warnings and hence lead to no action. Others could be inconvenient such as bad road planning after simulating traffic flow which leads to traffic queues into a busy town centre.

(4)

B3. Cyclone Yasi hit Northern Australia in February 2011. There were many after effects such as flooding and landslides.
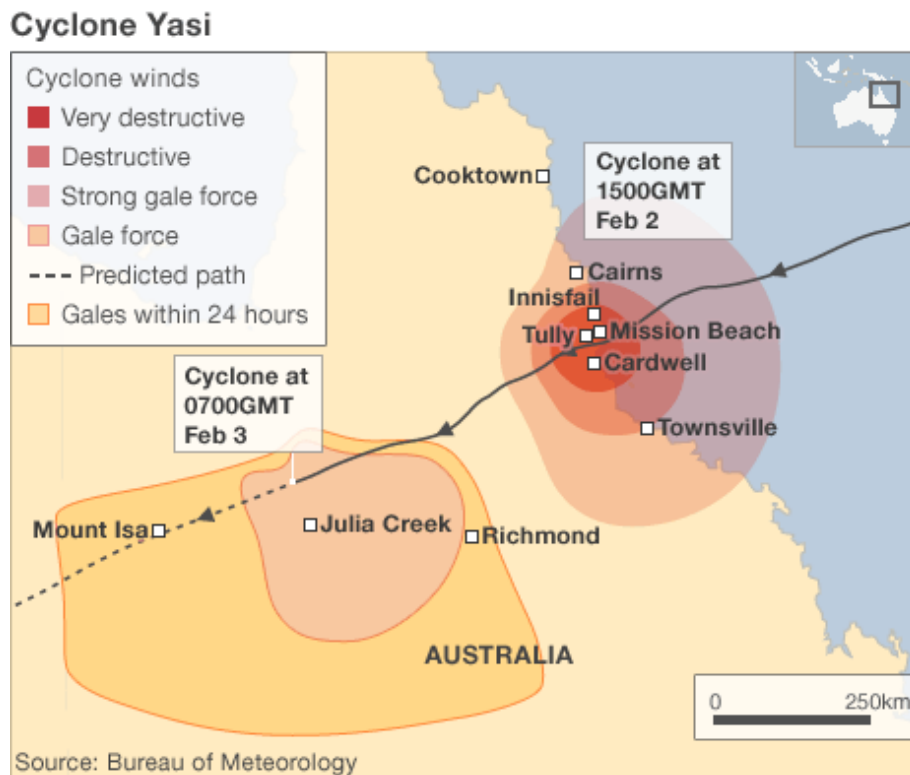
Source: Australian Government Bureau of Meteorology (07 February 2011)

To ensure that the emergency services could be located where they will be most needed a 2D visual model of likely danger areas, shown above, was created and distributed to surrounding areas in real time.

(a) Outline the ways in which visualisation can be used to display the possible effects of the Cyclone in real time.   [4 marks]

Data from the actual and past path can be collected continually. Data from past experience of cyclones can be used to make a model of cyclone behaviour. Feeding the known path data into the model a likely path could be calculated and applied to the area. Using a map of the affected area as a base the danger areas can be displayed as a 2D picture. As the cyclone advances the predicted path and the picture are updated.

(4)

(b) Explain the technical difficulties that could arise in data collection and processing when attempting to predict in real time. [4 marks]

Data collection would rely on transmission media working from the centre of the cyclone, and around it, to the computers that are used for calculation. Most probably this would be done by satellite but strength of cyclone and damage caused are also needed and may not be easily transmitted from the centre of the cyclone, which is constantly moving. If some data is not transmitted correctly, the model could produce inaccurate predictions.
Real time processing needs very precise data input and has complicated calculations to make, hence the computer needs to be a powerful one. There is also the question of security, as if the computer fails then there is no prediction. The solution would be for the data to be distributed to more than one centre so that a breakdown would not stop the model being created.

4

(c) Explain the advantages of using visualisation in this case. [6 marks]

In this situation, using visualisation provides a quick way to view the data predicted by the model. It can quickly show the location and predicted severity of any effects. If the information is presented numerically then interpretation will be needed which will be time consuming in a situation where the aim is to quickly see the danger zones and send the emergency services to those areas. Also, the changing of the visualisation in real time provides a simple way to view not only the situation but the development of the situation and may give an insight into future problems. It is also widely distributable which means that the situation can be seen world wide and aid sent from other countries if appropriate.

Concisely and clearly explained.

6

(d) Compare the use of 2D with 3D visualisation in this situation. [3 marks]

The processing needs of 3D visualisation are significantly greater than those of 2D and hence more likely to be possible at more than one centre. The memory needed to hold and update the map is also much greater in 3D visualisation. In this case 2D is sufficient as the state of the cyclone is required over the surface only. One disadvantage would be if the effect at higher or lower altitudes was an important factor.

3

HL Extension

B4. "Rescue robots capable of understanding the changing and unpredictable environment of disaster scenarios may one day be deployed to search for survivors in the aftermath of earthquakes.

This is the vision of inventors Erwin Prassler and Ivan Bratko, who have developed a software algorithm that takes data from a robot's sensors as it moves through an area to create models and predict how objects in the vicinity will change their position relative to its movements.

Using the same algorithm, Bratko said that the robot can learn physical concepts such as whether an object is moveable and where it can be moved to. He added that it also gives the robot the ability to learn 'abstract concepts' such as the structural stability of an object."

Taken from "The Engineer" Tuesday, 05 October 2010
http://www.theengineer.co.uk/video/robots-could-be-used-in-earthquake-rescue-missions/1004650.article#ixzz11U3G8BUU

In this question you can assume that the robot is equipped with distance and angle sensors.

Robots involved in rescue are placed in an unknown environment and have to model the environment. Part of this process involves genetic algorithms.

(a) Outline, using examples, the difference between *supervised* and *unsupervised learning*.   [4 marks]

Supervised learning is when the algorithm has both the input and desired output and attempts to make a connection between the two, so success can be easily measured. In unsupervised learning only the input data is available and the algorithm attempts to find patterns.

Lacks some reference to applications.   ③

(b) Explain the way in which genetic algorithms help in the learning process.   [6 marks]

Genetic algorithms work by trying different approaches to the situation and improving the algorithm by keeping a certain percentage of the most successful approaches. A function of the success of each solution is defined to give a way for the learning process to measure success. These approaches are then varied and the process is run again to achieve a gradual improvement in the algorithm. The learning process is iterated through until a certain point where the algorithm is efficient enough or until a certain time has elapsed.

A very concise response that meets the requirements of the top level descriptor.   ⑥

(c) Describe the way in which the robot could model the situation in which it finds itself.   [4 marks]

As the robot is equipped with distance and angle sensors it is possible to build up a map of its environment based on the input from the sensors, specifically any walls or obstructions that may surround it. The robot will start with a value of its position which will change as it moves through the environment. While the robot moves through the environment the distance sensors will continually be reporting on the presence of any objects and using the distance from the robot combined with its position a map can be build up of obstacles and so the robot can use the map to avoid obstacles and find new clear paths.

4

Once the robot has found a victim, it needs to communicate this information back to emergency services.

(d) Suggest ways in which the robot and human rescue workers could communicate to make a successful rescue of a person.   [6 marks]

The robot will probably have a wireless link to human rescue workers so that its behaviour can be monitored and controlled if needed. Visualisation could be used so that human rescue workers will have an idea of the situation the robot is in and, if a victim is found, the situation that the victim is in. If the robot has measured the stability of obstacles that it has discovered then a rescue plan or path can be devised reducing the possibility of causing further collapses. The situation that victims are in could have low light conditions and may be surrounded by many obstacles that would dampen any sound so sensors other than those corresponding to human senses may have to be relied on. An infrared camera could be used to attempt to detect body heat and therefore survivors. The image could be transmitted back to rescue workers who could then provide further interpretation of the image such as the condition of the victim and so the difficulty of any rescue.

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