Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
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FACULTY OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

SCHOOL OF ENGINEERING

Electronic and Electrical Engineering

Engineering MAI/MSc **Semester 2, 2022**

EEP55C23 Computation for Transportation Engineering

04/05/2021 **RDS-MAIN HALL** **14:00–16:00**

Dr A. Staino and Prof. B. Basu

Instructions to Candidates:

Answer any four (4) questions.

Start the answer to each question on a new page.

Q.1 **[Total: 25 marks]**

(a) What are the main types of maintenance adopted in railway?

For each maintenance strategy, provide a brief description of the approach, and outline the respective main advantages and drawbacks.

Discuss what are the criteria inspiring the predictive maintenance approach, what are the main enablers for this strategy, and what are the basic steps of a prognostics and health management system.

[15 marks]

(b) What is the confusion matrix for binary classification?

Illustrate the structure of this matrix and describe the different elements it contains. With respect to the confusion matrix, what are the targets in the context of predictive maintenance?

[10 marks]

Q.2 **[Total: 25 marks]**

(a) You are a data analyst in a railway company.

The maintenance team from a rolling stock project provides one week of data relative to the performance of the traction system for a fleet of trains. The data stored in a pandas DataFrame whose first four rows are illustrated in Fig. Q.2 (a).

The info() method for the DataFrame prints the following information:

```
Data columns (total 8 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Date                  500 non-null    object
 1   Time                  500 non-null    object
 2   Day                   500 non-null    object
 3   Power                 500 non-null    int64
 4   Train Speed           500 non-null    int64
 5   External Temperature  500 non-null    object
 6   Car temperature       500 non-null    object
 7   Train Unit            500 non-null    int64
```

The subject matter expert tells you that, for a given train, the Power value on a hourly basis should not exceed the value '25'. Using functions from the pandas library, write a piece of code to identify what are the train units that need to be sent for maintenance inspection due to excessive Power usage.

Date	Time	Day	Power	Train Speed	External Temperature	Car temperature	Train Unit
2014/01/01	00:21	Wednesday	55	60	[4.18]	[14.73]	3
2014/01/01	02:06	Wednesday	3	7	[5.04]	[15.14]	2
2014/01/01	02:40	Wednesday	0	0	[4.99]	[15.81]	4
2014/01/01	03:10	Wednesday	3	8	[5.27]	[15.42]	8

Fig. Q.2 (a) **[25 marks]**

Q.3 **[Total: 25 marks]**

(a) Describe the concept of uncertainty propagation.

Why is it relevant for predictive maintenance?

[5 marks]

(b) What are the main steps to perform Monte Carlo uncertainty quantification?

[10 marks]

(c) In Monte Carlo simulations, how many iterations are required to estimate the mean of a target distribution, for a given percentage error bound ε and confidence interval z_(α/2)?

[5 marks]

Q.4 **[Total: 25 marks]**

(a) What is the purpose of signalling systems in railways?

List the main risks associated movements of trains on track networks.

[5 marks]

(b) Illustrate what are the possible strategies for train separation, with a description of the application of lineside signals in a fixed block operation.

[10 marks]

(c) What are the most common devices for detecting the presence of a train in a given section of track? Illustrate the main advantages and drawback of each detection system.

[10 marks]

Q.5 **[Total: 25 marks]**

(a) Consider a graphical network with four binary variables C, D, E and F.

The probability tables are given as follows:

$P(C)$

C_1	C_2
0.8	0.2

$P(E|C)$

	C_1	C_2
E_1	0.9	0.7
E_2	0.1	0.3

$P(F|E)$

	E_1	E_2
F_1	0.9	0.5
F_2	0.5	0.5

$P(D|E)$

	E_1	E_2
D_1	0.7	0.4
D_2	0.3	0.6

(i) Construct the network model.

(ii) Evidence shows that F = F1. Using a bottom-up propagation of Pearl's tree algorithm, update the inference that C = C1. If further evidence indicates that D = D1, then infer on the possibility of C = C1. **[10 marks]**

(b) Consider the 4 node Markov chain graphical model in Fig. Q.5 (c). Each node represents a binary variable. Calculate the marginal probability distribution for node 'a' by using variable elimination. Compare the improvement in computational complexity as compared to the naïve approach.

Fig. Q.5 (c) **[7 marks]**

(c) Construct a Bayesian network based on the qualitative statistical dependencies described as follows:

1. A storm in a particular geographical region (G) increases the chance of transmission line failure (L).
2. Voltage spike is a risk factor for both transformer fault (T) and damage to sensors (S).
3. The occurrence of either (E) transmission line failure or transformer fault can be manifested by interruption of power supply (P), but power outage alone cannot distinguish between them.
4. Malfunctioning of sensitive equipment (M) may be caused by damaged sensors (S), or either (E) transmission line failure or transformer fault.

Also, write the expression for the joint probability distribution taking into account the statistical dependencies. **[8 marks]**