Tutorial 2: Introduction to statistical pattern recognition

1. Given a two dimensional space with the following dataset:

   Class A: $(0,2)$, $(0,4)$, $(1,2)$, $(2,3)$
   Class B: $(2,1)$, $(3,1)$, $(3,3)$, $(4,4)$

   Classify a new point $(2,2)$ using k-nearest neighbour classification using Euclidean distances and $k=3$ and $k=5$.

2. 60% of mathematicians stare at your shoes when they meet you, but only 10% of engineers do. You are at an exciting party composed entirely of mathematicians and engineers. 80% of the people there are engineers. You meet someone who stares at your shoes. What is the probability that they are a mathematician?

3. A screening test is devised for a disease. It seems that the test is very accurate: 99% of people with the disease test positive; 95% of people who do not have the disease test negative. Of those who are given the test, 1% actually have the disease.

   (a) What percentage of subjects will test positive?

   (b) Given that a subject tests positive, what is the posterior probability that they have the disease?

4. Consider a fictitious medical condition C, which is either present ($C=1$) or absent ($C=0$) in a subject. The only information we have about a subject is whether they have a rash ($R=1$), have a temperature ($T=1$), or are dizzy ($D=1$). Thus we have a 3-dimensional feature vector, (R,T,D). If we have the following information about a subject: $R=1, T=0, D=1$, then the feature vector is $\mathbf{X}=(1,0,1)$.

   Training data are available from 40 subjects, shown in figure 1 (overleaf). Using this training data, estimate the likelihoods:
   $P(\mathbf{X}=(0,0,0) \mid C=1), \ldots, P(\mathbf{X}=(1,1,1) \mid C=1), \ldots, P(\mathbf{X}=(0,0,0) \mid C=0), \ldots, P(\mathbf{X}=(1,1,1) \mid C=0)$.

   The following test data are observed:

   $$\mathbf{x}_1=(1,1,1), \quad \mathbf{x}_2=(1,0,0), \quad \mathbf{x}_3=(0,1,0).$$

   It is known that the prior probability of the condition is $P(C=1)=0.25$. To which class should each test vector be classified?

   Comment on this approach to classification if we had a situation with a 10-dimensional feature vector, or if we have a situation where each input dimension has 5 possible values rather than 2.

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Inputs				Inputs			
R	T	D	C	R	T	D	C
0	1	0	0	1	0	0	0
1	1	1	1	0	0	0	0
0	0	0	0	1	0	1	1
1	0	0	1	0	1	0	1
1	1	0	1	1	1	1	1
0	0	0	0	1	0	1	0
1	1	1	0	0	0	0	0
0	1	1	1	1	0	1	0
1	0	0	0	1	0	0	1
1	1	1	1	0	0	1	0
1	0	1	0	1	1	0	1
1	0	1	1	0	1	1	0
1	1	0	1	1	0	1	1
0	1	0	1	0	1	0	0
0	1	0	0	0	0	0	0
1	1	1	1	1	1	0	1
0	0	0	0	0	0	1	0
0	0	1	0	1	0	0	1
1	1	1	1	0	1	0	0
0	0	0	1	0	0	1	1

Figure 1: Training data for question 4. Three input dimensions rash (R), temperature (T), dizzy (D); output class (C). All variables are binary.

5. This is an extension of the line of best fit discussed in Section 5.5.3 in Lecture Note 5 to a 3D case. Consider a set of N observations $\{\mathbf{p}_n\}_1^N$ in a 3D space, where $\mathbf{p}_n = (x_n, y_n, z_n)^T$, for which we would like to find the best fit plane $z = ax + by + c$. Derive the system of linear equations in $a, b,$ and c. (NB: It is more general to define a plane as $ax + by + cz + d = 0$, but we here consider a simpler version.)