CS-E5710 Bayesian Data Analysis
Assignment 1

September 15, 2019

1 Basic probability theory notation and terms

Probability deals with calculating the likelihood of a given event's occurrence, which is expressed as a number between 1 and 0.

Probability mass refers to the probability of samples on an interval, eg. the entire probability sample space is equal to 1.

Probability density is used to specify the probability of the random variable falling within a particular range of values, as opposed to taking on any one value.

Probability mass function (pmf) is a function that gives the probability that a discrete random variable is exactly equal to some value.

Probability density function (pdf) is a function whose value at any given sample (or point) in the sample space (the set of possible values taken by the random variable) can be interpreted as providing a relative likelihood that the value of the random variable would equal that sample.

Probability distribution is a function that describes the likelihood of obtaining the possible values that a random variable can assume.

Discrete probability distribution describes the probability of occurrence of each value of a discrete random variable.

Continuous probability distribution describes the probabilities of the possible values of a continuous random variable.

Cumulative distribution function (cdf) is the probability that will take a value less than or equal to.

Likelihood is the hypothetical probability that an event that has already occurred would yield a specific outcome and it refers to past events with known outcomes.

2 Basic computer skills

a) Plot the density function of Beta-distribution

```
from scipy import stats
import numpy as np
import matplotlib.pyplot as plt

MEAN = 0.2
VARIANCE = 0.01

alpha = MEAN * ( (MEAN * (1 - MEAN) / VARIANCE) - 1 )
beta = alpha * (1 - MEAN) / MEAN

x_range = np.linspace(0, 1, 100)
y_range = stats.beta.pdf(x_range, alpha, beta)

plt.plot(x_range, y_range)
plt.xlabel('probability')
plt.ylabel('density')
plt.savefig('./distribution.png')
```

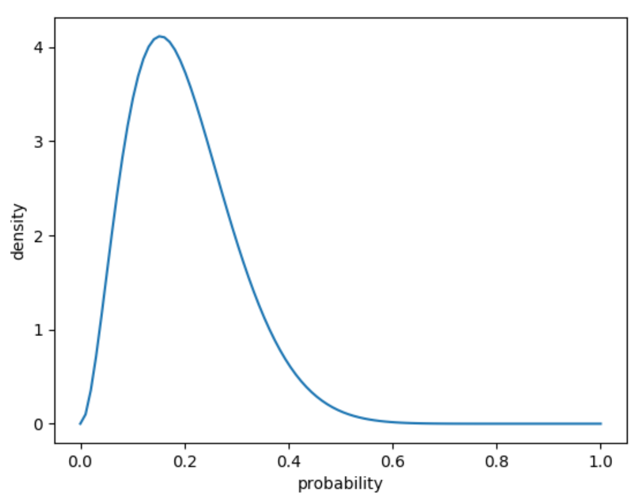

Figure 1: density function of Beta-distribution

b) Take a sample of 1000 random numbers and plot a histogram

```
random_samples = stats.beta.rvs(alpha, beta, size=1000)
plt.hist(random_samples, density=True, alpha=0.5)
plt.savefig('./distribution_hist.png')
```

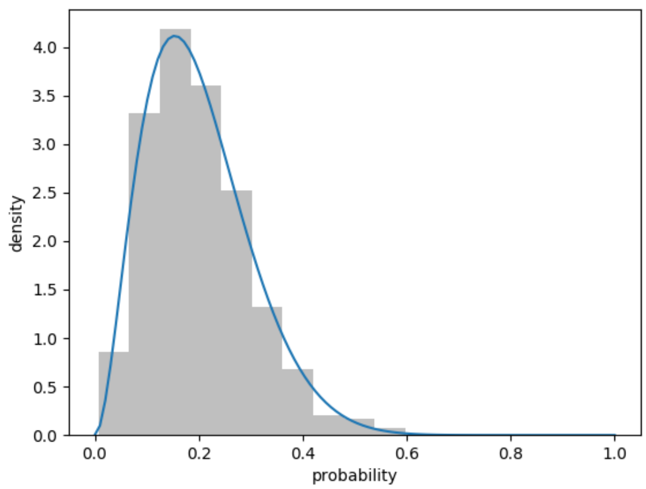

Figure 2: histogram of 1000 samples

c) Compute the sample mean and variance from the drawn sample

```
sample_mean = np.mean(random_samples)
sample_variance = np.var(random_samples)
print('sample mean: ', sample_mean)
print('sample variance: ', sample_variance)
```

Sample mean: 0.19936416481824012
Sample variance: 0.009874950476577216

d) Estimate the central 95%-interval of the distribution from the drawn samples

```
sample_percentile = np.percentile(random_samples, q=2.5),
                    np.percentile(random_samples, q=97.5)
print('sample central percentile 95%: ', sample_percentile)
```

Sample central percentile 95%: (0.04437716914185335, 0.4501785407399954)

3 Bayes' theorem

Given Event C: test subject has lung cancer, Event Y: test gives a positive result.

$P(C) = 0.001,\ P(Y|C) = 0.98,\ P(Y) = 0.999 \times 0.04 + 0.001 \times 0.98 = 0.04094,$

According to Bayes' theorem, $P(C|Y) = \frac{P(Y|C)P(C)}{P(Y)} = 0.02393$

We could see the probability of a random selected test subject having cancer given a positive result is 2.393%. I would suggest researcher to improve their prediction accuracy and attach more importance to other factors causing cancer rather than test results ,e.g. families cancer history, bad habits, etc. These could reduce P(C).

4 Bayes' theorem

a) $P(red) = 0.4 \times \frac{2}{7} + 0.1 \times \frac{4}{5} + 0.5 \times \frac{1}{4} = 0.3193$

The probability of picking a red ball is 31.93%.

b) $P(A|red) = \frac{P(red|A)P(A)}{P(red)} = 0.3579$

$P(B|red) = \frac{P(red|B)P(B)}{P(red)} = 0.2505$

$P(C|red) = \frac{P(red|C)P(C)}{P(red)} = 0.3914$

If a red ball was picked, it most probably came from box C.

5 Bayes' theorem

Given: Event S is a notation of same gender twins, I stands for identical twins and F means fraternal twins. We need to find $P(I|S)$.

$P(S) = P(I) + P(F\ for\ the\ same\ gender) = \frac{1}{300} + 0.5 \times \frac{1}{125} = 0.0073$

$P(I|S) = \frac{P(Elvis\ being\ twin) \times P(I)}{P(S)} = \frac{1 \times \frac{1}{300}}{0.0073} = 0.45$

The probability that Elvis was an identical twin is 45%.