
TMA4255 Applied Statistics
Exercise 11

Problem 1

One wants to monitor an electric signal (in dB) that characterizes a particular electric component.

Sample	x_1	x_2	x_3	x_4	x_5
1	15.5	16.5	14.4	15.0	16.6
2	16.1	15.2	14.9	14.6	16.3
3	14.9	16.9	16.2	17.2	16.8
4	16.6	16.0	16.6	16.8	16.9
5	15.7	16.2	16.1	16.5	15.9
6	15.9	15.2	13.7	15.9	16.0
7	16.1	15.5	17.5	14.6	16.9
8	16.1	15.0	16.9	16.1	16.8
9	10.9	16.6	12.9	16.8	15.6
10	15.0	13.0	15.7	15.8	17.1
11	16.8	15.6	14.9	14.0	16.3

Rational subgroups of size $n = 5$ are used.

Use these data as training data and set up $\bar{X} - S$ and S -charts for the data. Comment

Problem 2

The number of defective transistors out of 1000 inspected has been registered during one month. Use the given data as training data and set up a p -chart. Comment.

Day	Number of defective transistors	Day	Number of defective transistors
1	7	16	10
2	5	17	9
3	11	18	12
4	13	19	14
5	9	20	12
6	12	21	13
7	10	22	7
8	10	23	9
9	6	24	12
10	14	25	8
11	9	26	14
12	13	27	12
13	8	28	12
14	11	29	11
15	12	30	13

Problem 3

During teeming of metal bolts the number of pores in a certain area is registered.

Bolt	Number of pores	Bolt	Number of pores
1	9	14	3
2	15	15	7
3	11	16	2
4	8	17	3
5	17	18	3
6	11	19	6
7	5	20	2
8	11	21	7
9	13	22	9
10	7	23	1
11	10	24	5
12	12	25	8
13	4	26	8

Use these data as training data and set up a c -chart. Comment.

Problem 4: Goodness of fit test

This problem requires both theoretical work and use of software.

Some hand dryers will blow hot air for a time t_0 once you turn them on and then they are automatically turned off. If the hands are not dry during the time t_0 , the machine has to be turned on again.

We assume that the time T (in seconds) that a randomly selected individual needs to get the hands dry is gamma distributed $(2, \theta)$ with probability density function

$$f(t) = \frac{t}{\theta^2} e^{-\frac{t}{\theta}} \text{ for } t > 0 \quad (1)$$

where $\theta = E(T)$ is an unknown parameter. Alternatively you may use that for $T \sim \text{gamma}(2, \theta)$ it is also known that $Z = \frac{2T}{\theta} \sim \chi_4^2$ (chi-squared-distributed with 4 degrees of freedom). (So you either use the gamma or the chi-square distribution in calculating probabilities and expected values. Both are available in MiniTab and in R, and you need to perform this part of the calculations with software.)

Assume that n individuals have used this kind of hand dryer and that their drying times $T_1, \dots, T_n$ are independently and identically distributed with the probability density function given in 1. The standard estimator (maximum likelihood) for θ is then

$$\bar{T} = \frac{1}{n} \sum_{i=1}^n T_i \quad (2)$$

Assume that $n = 60$ and $\sum_{i=1}^{60} T_i = 1800$, so that $\bar{T} = 1800/60 = 30$. (Remark: you need to use this estimator for the unknown θ in your calculation.)

One wants to test if T has the probability density function 1. Use the data and the separation in intervals as given in the table below. Choose the null hypothesis and alternative hypothesis yourself.

Interval no.	Intervall	Number of observations in the interval (X_j)
1	$< 0, 25]$	12
2	$< 25, 40]$	7
3	$< 40, 55]$	11
4	$< 55, 70]$	12
5	$< 70, 90]$	8
6	$< 90, \infty]$	10

Problem 5: Test for independence

This problem can be solved using software alone.

The health authorities are interested in knowing whether the consumption of skimmed, semi-skimmed and homogenized milk is the same among young people as among the older ones. A survey has been conducted where 500 adults were asked about their age and what kind of milk they drink. The results were as follows:

	Skimmed milk	Semi-skimmed milk	Homogenized milk	Total
Age < 45	138	83	64	285
Age > 45	64	67	84	215
Total	202	150	148	500

Formulate the situation as a hypothesis testing problem. Perform the test using a 5% significance level.

Problem 6: Homogeneity

Exam August 2012, Problem 1: Use of cannabis among youths in Norway. See the course WWW-page. This is done by hand (no software at the exam).

Minitab

Problem 1:

Stat→Control Charts →Variables Charts for Subgroups → Xbar-S
 • Obs. from subgroups are in one row across columns: C2-C6

Problem 2:

Stat→Control Charts → Attributes Charts → P
 Variable: C2
 • Subgroup size: 1000

Problem 3: Stat→Control Charts → Attributes Charts→ C
 Variable: C2

Problem 4) Put the interval limits in one column and the number of observations in another column and perform operations on these columns to first find the probability of observing a time within the interval (based on $\text{gamma}(2, \theta)$ or Chi-squared 4), then the expected number of events in the intervals, and finally the χ^2 test statistic and the corresponding p -value.

Problem 5) Stat $\rightarrow$ Tables $\rightarrow$ Chi-Square Test.

R:

We may use the R-library `qcc`. See the help pages for details. The `qcc` function takes a data set and specification of which plot to be made as arguments.

```
install.packages("qcc")
library(qcc)
?qcc

# Problem 1
data1 <- read.table("http://www.math.ntnu.no/~mettela/TMA4255/Data/data10_1.txt")
data1
cc1XS <- qcc(data=data1,type="xbar",std.dev="UWAVE-SD")
cc1S <- qcc(data=data1,type="S")
# leaving out observation at row 9
cc1Sm9<- qcc(data=data1[-9,],type="S")
cc1XSm9 <- qcc(data=data1[-9,],type="xbar",std.dev="UWAVE-SD")

# Problem 2
data2 <- scan("http://www.math.ntnu.no/~mettela/TMA4255/Data/data10_2.txt")
data2
# binomial data with n=1000
cc2p <- qcc(data2,type="p",sizes=1000)

# Problem 3
data3 <- scan("http://www.math.ntnu.no/~mettela/TMA4255/Data/data10_3.txt")
data3
# binomial data with n=1000
cc3c <- qcc(data3,type="c")
# violation for obs 5
cc3cm5 <- qcc(data3[-5],type="c")
```

Problem 4) First read in the interval limits, and use the gamma or chisq-distribution to calculate probabilities for each interval. For all probability distributions *pdist* gives cumulative probabilities, where *dist* is replaced with e.g. gamma or chisq. Then use $P(T \leq U) - P(T \leq L)$ (U=upper, L=lower) to find the probability to be inside the interval. Then multiply with $n = 60$ and we have the expected cell counts under the null hypothesis. Then calculate the chi-squared goodness of fit test statistic and compare with the correct chi-squared distribution. The degree of freedom is then “number of cells - 1 - number of parameters estimated”, and we have estimated one parameter.

```

thetaest<-1800/60
lowerL <- c(0,25,40,55,70,90)
# probabilities for each interval can be calculated using the gamma for T
# first using gamma to find the prob of being lower than equal to the lower
# interval limit
intprobL <- pgamma(lowerL,shape=2,rate=1/thetaest)
# for comparison, also chisq 4 for 2*T/theta
intprobL2 <- pchisq(lowerL*2/thetaest,4)
# check: this gives the same - not use intprobL2 further - just compare

# prob of being lower than upper limit, shuffle and add 1
intprobU <- c(intprobL[-1],1)
intprob <- intprobU-intprobL
# expected in each interval, multiply intprob with n=60
e <- intprob*60
# entering the observed values
o <- c( 12,7,11,12,8,10)
# (o-e)^2/e and sum
testobscell <- (o-e)^2/e
testobs <- sum(testobscell)
# compare with chisq distribution with 6-1-1=4 degrees of freedom
# since 6 cells, all sum to 1 (minus 1), and estimated theta (minus 1).
# p-value
pchisq(testobs,4,lower.tail=FALSE)
# critical value, just for comparison - how large need to be for rejection
qchisq(0.05,4,lower.tail=FALSE)
#9.487729

```

Problem 5) First read the data into a matrix, one row for each sample. Use the function `chisq.test` which takes the 2 by 3 matrix of data as input. Choose the `correct=FALSE` option to skip the continuity correction.

```

milktab <- rbind(c(138,83,64),c(64,67,84))
chisq.test(milktab,correct=FALSE)

```