732A96 Lab 2

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Question 1

```
states <- paste("z",1:10,sep = "")
symbols <- paste("s",1:10,sep = "")
start <- rep(0.1,10)

#Just to see the structure
#initHMM(states, symbols)

# The transition probabilities, since we only can move
trans <- matrix(0,ncol = 10, nrow = 10)
diag(trans) <- 0.5
diag(trans[,-1]) <- 0.5
trans[10,1] <- 0.5
#trans[1,10] <- 0.5

# Making sure the probabilities sum to 1 in each row
#apply(trans, MARGIN = 1, FUN = sum)

emission <- matrix(0,ncol = 10, nrow = 10)
diag(emission) <- 0.5

# The Emission probabilities are our uncertaintiec in the position of the robot.

# Brute force set up, Nick, Rasmus and Sascha probably has a nicer ways of solving this
diag(emission[,-1]) <- 0.2
diag(emission[-1,]) <- 0.2
diag(emission[c(-1:-2),]) <- 0.2
diag(emission[,c(-1:-2)]) <- 0.2
emission[10,2] <- 0.2
emission[2,10] <- 0.2
emission[2,10] <- 0.2
emission[1,10] <- 0.2
emission[9:10,1] <- 0.2
emission[1,9] <- 0.2
```

```
# The different places the robot can be in
symbols
```

```
##  [1] "s1"  "s2"  "s3"  "s4"  "s5"  "s6"  "s7"  "s8"  "s9"  "s10"
```

```
# The Hidden States
states
```

```
##  [1] "z1"  "z2"  "z3"  "z4"  "z5"  "z6"  "z7"  "z8"  "z9"  "z10"
```

```
# Where they start
start
```

```
##  [1] 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1
```

```
# Transition matrix is the probabilities the robot will move
trans
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
##  [1,]  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0   0.0
##  [2,]  0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0  0.0   0.0
##  [3,]  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0  0.0   0.0
##  [4,]  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0  0.0   0.0
##  [5,]  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0  0.0   0.0
##  [6,]  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0  0.0   0.0
##  [7,]  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5  0.0   0.0
##  [8,]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.5   0.0
##  [9,]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5   0.5
## [10,]  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0   0.5
```

```
# Emission matrix states the uncertainties we have about the robots position
emission
```

```
##       [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10]
##  [1,]  0.5  0.2  0.2  0.0  0.0  0.0  0.0  0.0  0.2   0.2
##  [2,]  0.2  0.5  0.2  0.2  0.0  0.0  0.0  0.0  0.0   0.2
##  [3,]  0.2  0.2  0.5  0.2  0.2  0.0  0.0  0.0  0.0   0.0
##  [4,]  0.0  0.2  0.2  0.5  0.2  0.2  0.0  0.0  0.0   0.0
##  [5,]  0.0  0.0  0.2  0.2  0.5  0.2  0.2  0.0  0.0   0.0
##  [6,]  0.0  0.0  0.0  0.2  0.2  0.5  0.2  0.2  0.0   0.0
##  [7,]  0.0  0.0  0.0  0.0  0.2  0.2  0.5  0.2  0.2   0.0
##  [8,]  0.0  0.0  0.0  0.0  0.0  0.2  0.2  0.5  0.2   0.2
##  [9,]  0.2  0.0  0.0  0.0  0.0  0.0  0.2  0.2  0.5   0.2
## [10,]  0.2  0.2  0.0  0.0  0.0  0.0  0.0  0.2  0.2   0.5
```

With everything defined we can initialize the HMM-robot.

```
robot <- initHMM(states,symbols,start,trans,emission)
```

Question 2

The function below is built for answering Question 2,3,4 and 5

```
mrRobot <- function(hmm,simobs = 100, what = "acc"){

  # Simulation the robot simobs times
  sim_rob <- simHMM(hmm,length = simobs)
```

```r
#extract the observations (x_t)
observations <- sim_rob$observation

#extract the hidden states z_t
state_place <- sim_rob$states


# Forward function computes the filtering with log
log_filter <- forward(hmm = hmm, observation = observations)

# Remove the log-transformation
filter <- exp(log_filter)

# Normalizing
norm_filter <-prop.table(filter, margin = 2)

# Checking which probability in each column is the highest
most_prob_filter <- apply(norm_filter, MARGIN = 2, FUN = which.max)

# Accuracy for the filter
accuracy_filter <-  sum(paste("z",most_prob_filter, sep = "")
                     == state_place) / length(state_place)

# Smoothed (in this package called the posterior)
smoothed <- posterior(hmm=hmm,observations)

# Normalizing
norm_smoothed <-prop.table(smoothed, margin = 2)

most_prob_smoothed <- apply(norm_smoothed, MARGIN = 2, FUN = which.max)

# Accuracy for the smoothed
accuracy_smoothed <-  sum(paste("z",most_prob_smoothed, sep = "")
                          ==  state_place) / length(state_place)

#cat("The accuracy of the smoothed is",accuracy_smoothed)


# Most probable path (Viterbi)
mpp <- viterbi(hmm,observations)

accuracy_mpp <-  sum(mpp == state_place) / length(state_place)
#cat("The accuracy of the Viterbi is",accuracy_mpp)


#Just logical statements on what to return.
if(what == "acc"){
return( c(accuracy_filter = accuracy_filter,
          accuracy_smoothed = accuracy_smoothed,
          accuracy_mpp = accuracy_mpp))
}

if(what == "filter"){
```

```
    return(norm_filter)
  }

  if(what == "smooth"){
    return(norm_smoothed)
  }

  if(what == "mpp"){
    return(mpp)
  }

}
```

Filter

```
mrRobot(hmm = robot,simobs = 100, what = "filter")
```

To much to print out, so run the code if you want to see the distribution ## Smoothed

```
mrRobot(hmm = robot,simobs = 100, what = "smooth")
```

To much to print out, so run the code if you want to see the distribution

Most probable path

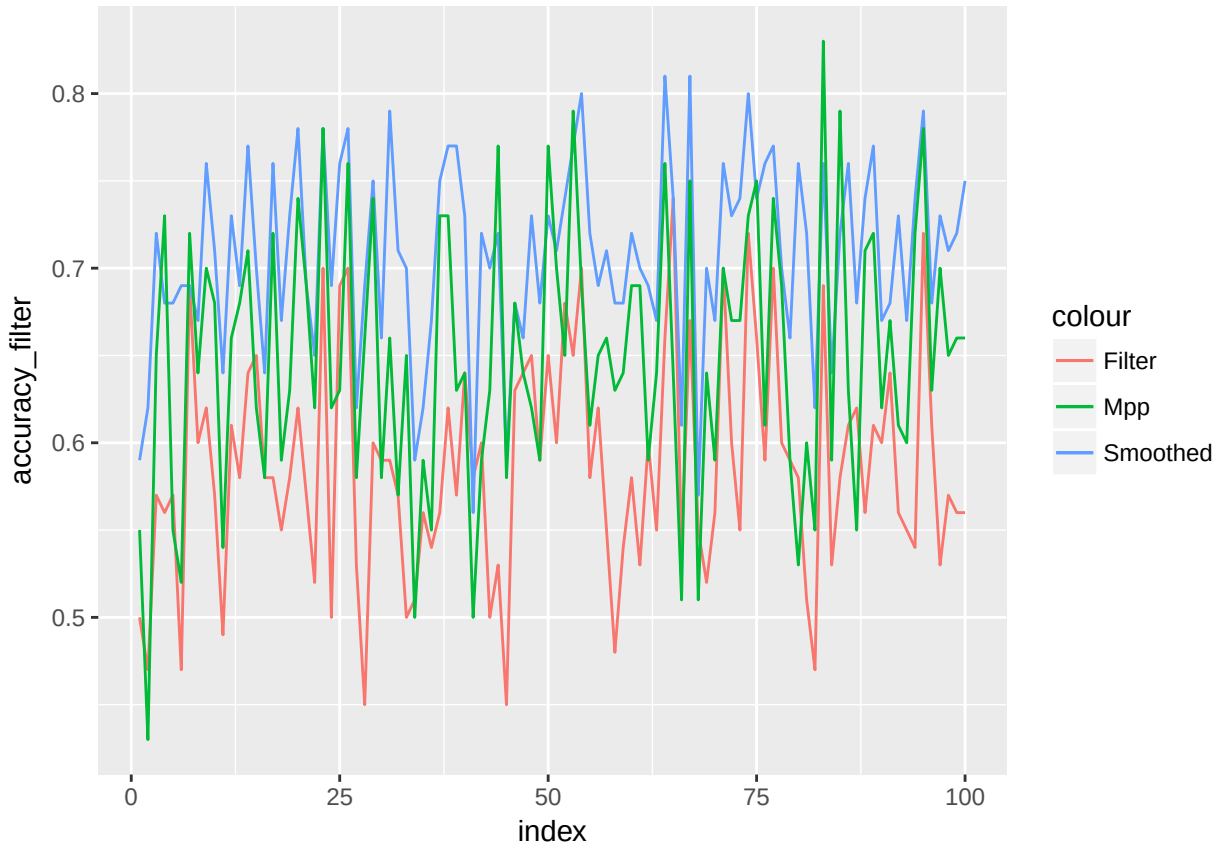
```
mrRobot(hmm = robot,simobs = 100, what = "mpp")
```

```
##   [1] "z3"  "z4"  "z4"  "z5"  "z5"  "z5"  "z5"  "z6"  "z7"  "z8"  "z8"
##  [12] "z9"  "z10" "z1"  "z1"  "z1"  "z2"  "z3"  "z4"  "z4"  "z4"  "z4"
##  [23] "z4"  "z4"  "z5"  "z5"  "z6"  "z7"  "z7"  "z7"  "z7"  "z8"  "z8"
##  [34] "z9"  "z10" "z1"  "z1"  "z1"  "z2"  "z2"  "z2"  "z3"  "z4"  "z4"
##  [45] "z5"  "z5"  "z6"  "z7"  "z8"  "z9"  "z9"  "z9"  "z10" "z1"  "z2"
##  [56] "z3"  "z4"  "z5"  "z5"  "z6"  "z6"  "z7"  "z7"  "z7"  "z8"  "z9"
##  [67] "z9"  "z9"  "z10" "z10" "z1"  "z1"  "z1"  "z1"  "z2"  "z3"  "z4"
##  [78] "z5"  "z5"  "z6"  "z7"  "z8"  "z8"  "z8"  "z8"  "z9"  "z10" "z1"
##  [89] "z2"  "z2"  "z3"  "z3"  "z4"  "z5"  "z6"  "z7"  "z7"  "z7"  "z7"
## [100] "z7"
```

```
total_acc <- sapply(1:100,FUN = function(x){mrRobot(robot,100, what = "acc")} )

total_acc <- as.data.frame(t(total_acc))
total_acc$index <- 1:100


ggplot(data = total_acc) + geom_line(aes(x=index,y=accuracy_filter , col = "Filter")) +  geom_line(aes(
```




```
colMeans(total_acc[,-4])
```

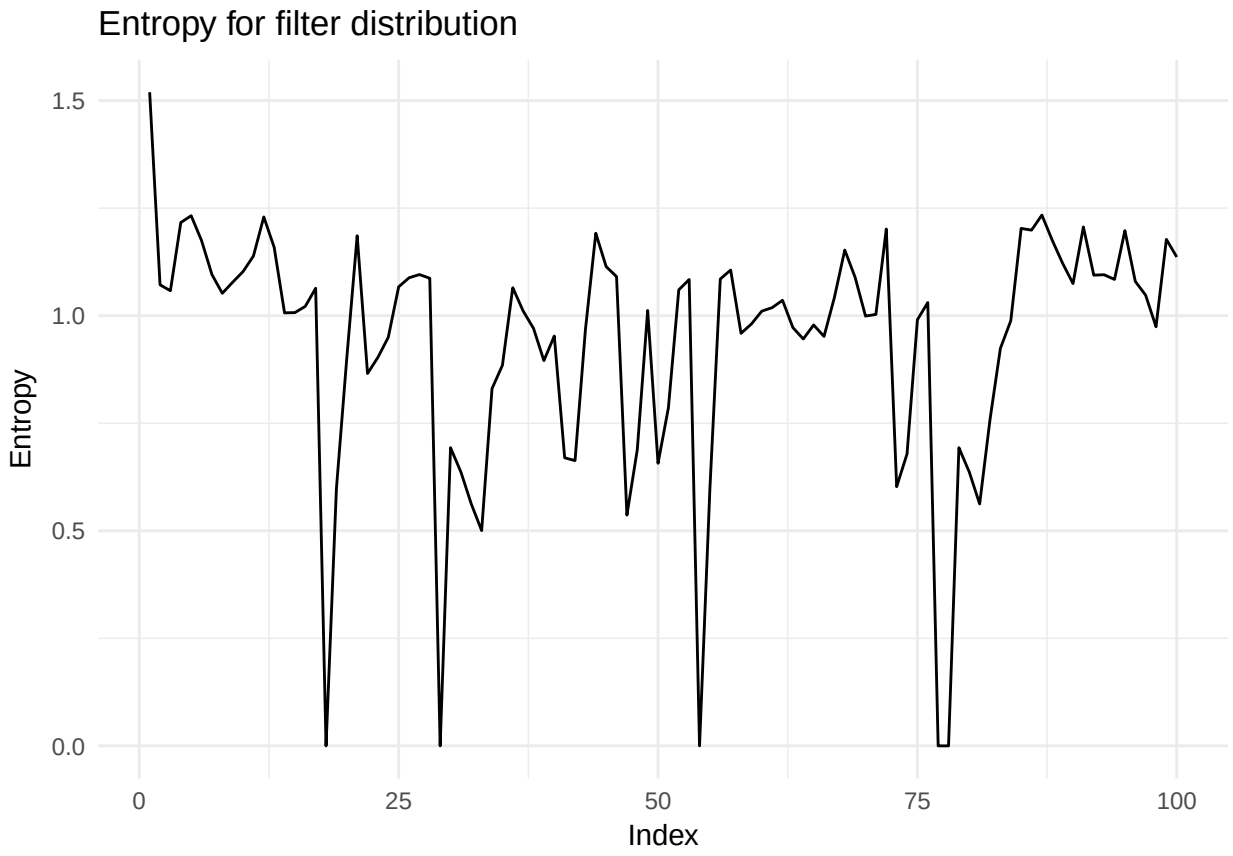
```
##   accuracy_filter accuracy_smoothed      accuracy_mpp
##            0.5864            0.7075            0.6490
```

Question 6

```
# filter_data <- sapply(1,FUN = function(x){
#   mrRobot(robot,100, what = "filter")
#   })

filter_data <- mrRobot(robot,100, what = "filter")
filter_entropy <- data.frame(Index = 1:100 ,
                  Entropy =
                  apply(filter_data, MARGIN = 2, FUN =entropy.empirical))

ggplot(data = filter_entropy, aes(x = Index, y = Entropy)) + geom_line() + ggtitle("Entropy for filter
```


Entropy for filter distribution
Entropy
1.5
1.0
0.5
0.0
0
25
50
75
100
Index

Question 7

???