

## Smoothing discrete data (II)

– using a hidden Markov model as implemented in the **mhsmm** package

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We apply the **mhsmm** package for a simple smoothing task. The data pertain to classification of a cows eating behaviour over time. The true eating status  $S_t$  is in the vector **cls0** where '1' denotes not eating and '2' denotes eating. The time resolution is one minute. The observed variables  $x_t$  in **cls1** are actually not observations per se but the result of a classification obtained by a neural network (using **nnet()** from the **nnet** package).

See also the vignette “Smoothing discrete data (I)” for an alternative approach to smoothing the data.

```
> load("clsX.RData")
> length(cls0)

[1] 8640

> length(cls1)

[1] 8640

> library(mhsmm)

> plot(cls1[1:2000], type = "l", ylim = c(0.8, 2))
> addStates(cls0[1:2000])
```

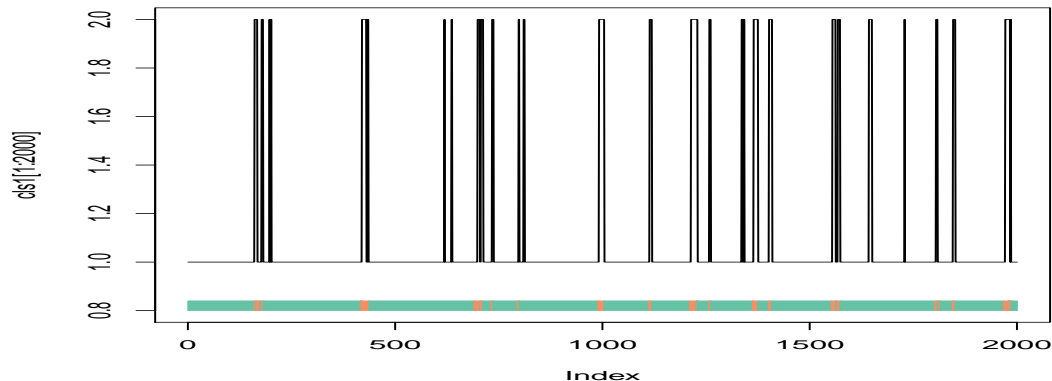


Figure 1: Observed and true eating states

A simple ‘smoothing’ of the observed states can be obtained as follows:  
The density function for the emission distribution is

```
> dpmf <- function(x, j, model) model$params.emission$pmf[j, x]
```

An initial setting of the parameters is as follows:

```
> J <- 2
> init <- c(0.5, 0.5)
> P <- matrix(c(0.9, 0.1, 0.1, 0.9), nrow = J)
> B <- list(pmf = matrix(0.1, ncol = J, nrow = J))
> diag(B$pmf) <- 0.9
> init.spec <- hmmspec(init, trans = P, parms.emission = B, dens.emission = dpmf)
> init.spec
```

Hidden Markov Model specification:

J (number of states):

2

init:

[1] 0.5 0.5

transition:

[,1] [,2]

[1,] 0.9 0.1

[2,] 0.1 0.9

emission:

\$pmf

[,1] [,2]

[1,] 0.9 0.1

[2,] 0.1 0.9

To fit the model we need to provide the function for the M-step of the EM-algorithm:

```
> mstep.pmf <- function(x, wt) {
+   ans <- matrix(ncol = ncol(wt), nrow = ncol(wt))
+   for (i in 1:ncol(wt)) for (j in 1:ncol(wt)) ans[i, j] <- sum(wt[which(x ==
+     j), i])/sum(wt[, i])
+   list(pmf = ans)
+ }
```

For training the model we use the first 1000 cases

```
> samp <- 1:2640
> train <- list(s = cls0[samp], x = cls1[samp], N = length(cls0[samp]))
> valid <- list(x = cls1[-samp], N = length(cls1[-samp]))
```

We fit the model with

```
> hmm.obj <- hmmfit(train, init.spec, mstep = mstep.pmf)
> summary(hmm.obj)
```

init:

1 0

transition:

[,1] [,2]

[1,] 0.983 0.017

[2,] 0.177 0.823

emission:

\$pmf

[,1] [,2]

[1,] 0.999756954 0.0002430464

[2,] 0.008608553 0.9913914471

Two types of predictions can be made: Default is to use the Viterbi algorithm for producing the jointly most likely sequence of states given the observed data:

```
> vit <- predict(hmm.obj, valid)
```

Alternatively we can get the individually most likely state sequence as:

```
> smo <- predict(hmm.obj, valid, method = "smoothed")
```

The prediction results are quite similar:

```
> normtab <- function(tt) round(sweep(tt, 1, rowSums(tt), "/"),
+ 2)
> SS <- cls0[-samp]
> XX <- cls1[-samp]
> cls2.vit <- vit$s
> cls2.smo <- smo$s
> normtab(table(SS, XX))
```

```
      XX
SS    1    2
1 0.98 0.02
2 0.27 0.73
```

```
> normtab(table(SS, cls2.vit))
```

```
      cls2.vit
SS    1    2
1 0.98 0.02
2 0.26 0.74
```

```
> normtab(table(SS, cls2.smo))
```

```
      cls2.smo
SS    1    2
1 0.98 0.02
2 0.26 0.74
```

```
> show <- 1:2000
> cls0b <- cls0[-samp]
> cls1b <- cls1[-samp]
> c(length(SS), length(cls2.vit), length(cls2.smo), length(cls0b),
+   length(cls1b))
```

```
[1] 6000 6000 6000 6000 6000
```

```
> plot(cls1b[show], type = "l", ylim = c(0.8, 2))
> addStates(list(cls0b[show], cls2.vit[show], cls2.smo[show]))
```

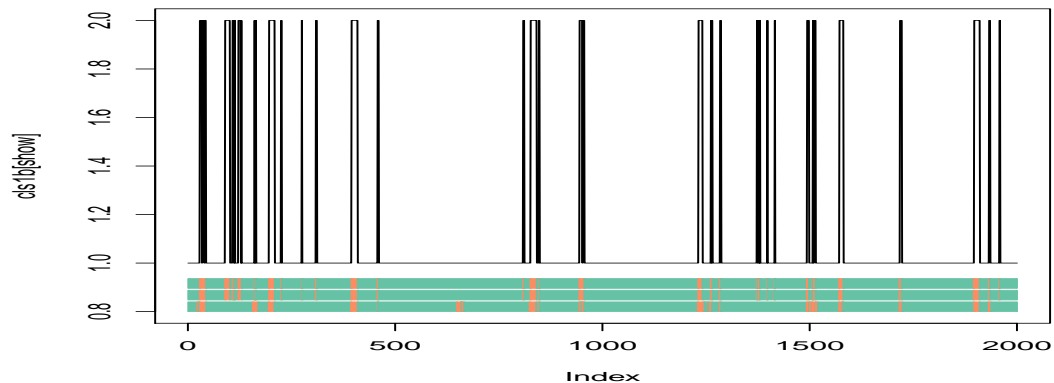


Figure 2: Observed and true eating states