Communication Technologies 1 (CT1)

Machine Learning

Viterbi Algorithm

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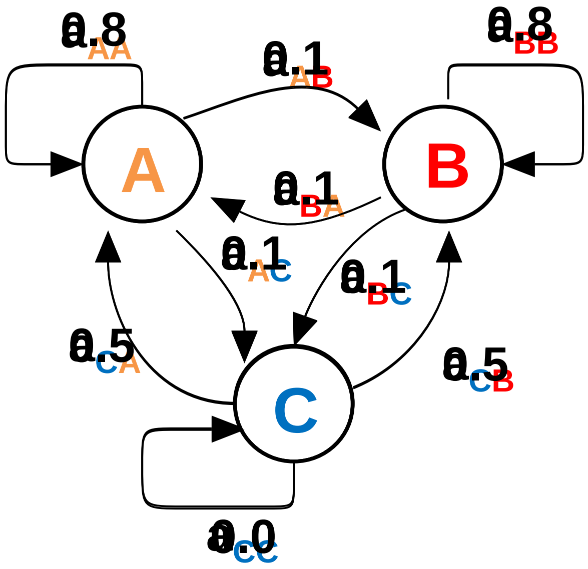
Agenda

- Introduction
- Viterbi Algorithm
- Experiment
- Summary
- Questions

Introduction

- Algorithm to recreate state sequences
- Example student travels between rooms

Marcov chain

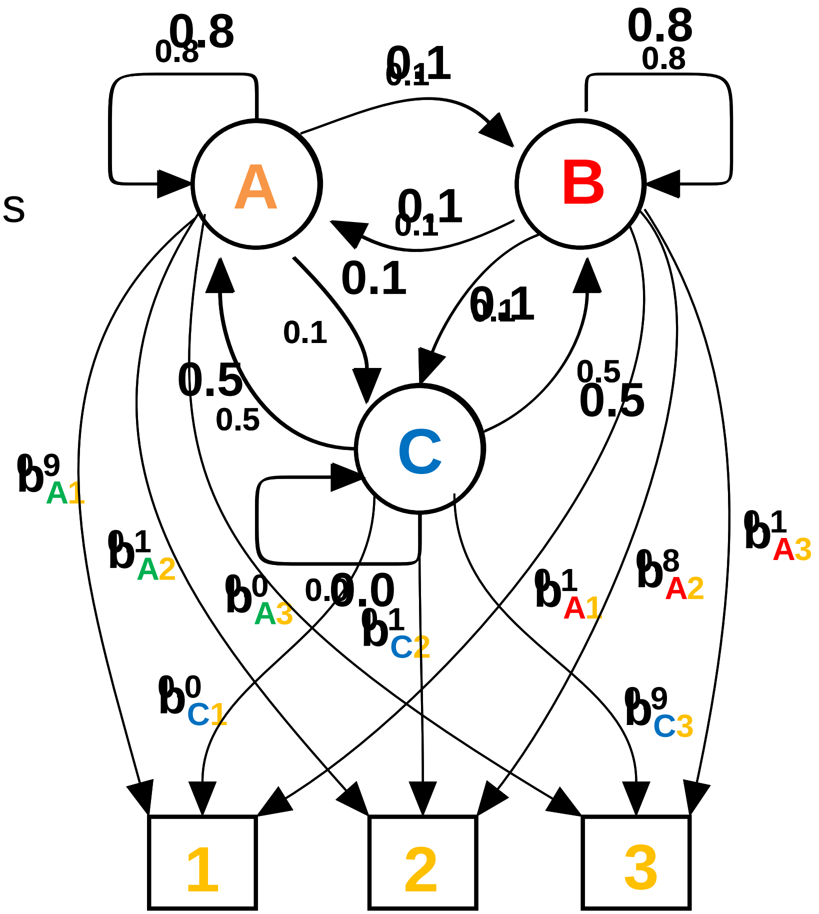


a_{ij} : transition probability from one state to the next

Introduction – Hidden Markov Model (HMM)

- State space S={A, B, C}
- Initial probability of states
- Transition matrix A that store the transition probability between true states

- Observation space O={1, 2, 3}
- Emission matrix B that stores the transition probability from true states to observing states
- Sequence of observations $y_1, y_2, .., y_T$



b_{ij} : probability of an observation for a hidden state

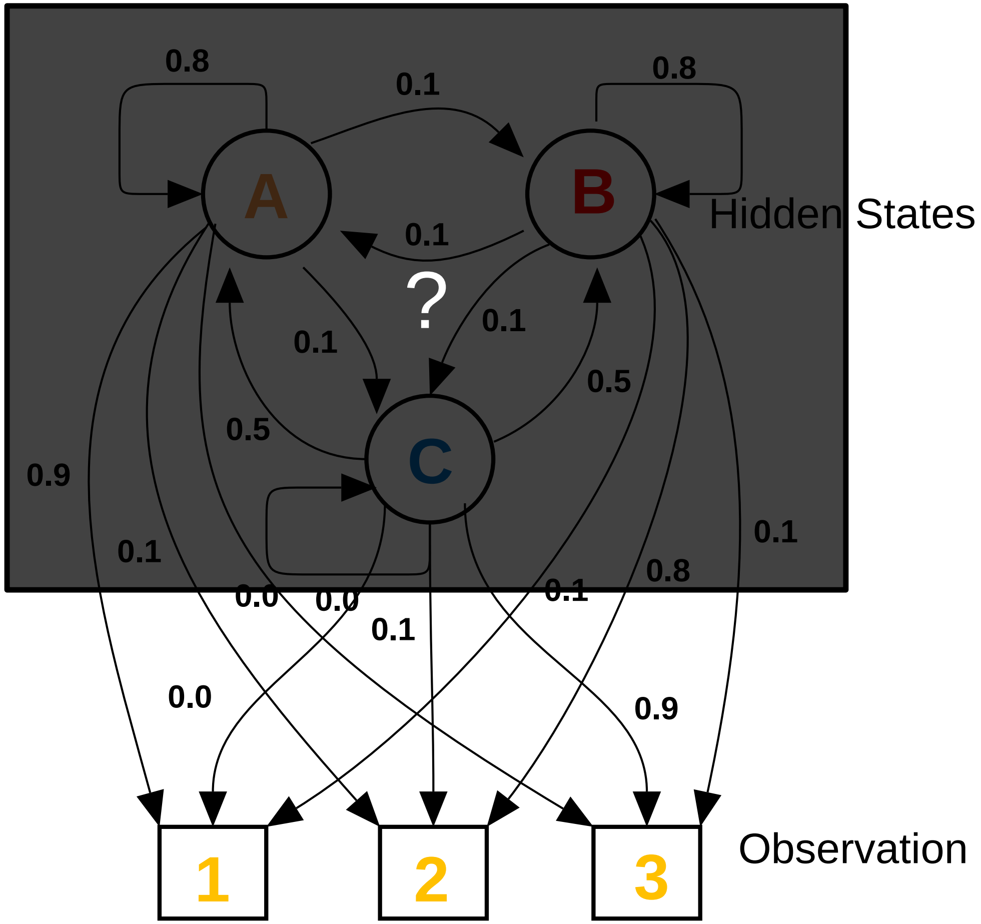
Introduction - Observations

Problem:
We don‘t know the true states of a HMM

Given:
HMM with observed states and transition probabilities

Target:
Estimate the true state (hidden state)

How:
Use the observations of the system
-> emission is visible and gives a stochastically hint



Viterbi Algorithm

- Invented by Andrew J. Viterbi in 1967
- Input via HMM and state sequence
- Calculates path with highest probability
- Used for decodation of convolutial codes
- Extended by G. D. Forney for reduction of communication errors

Viterbi Algorithm - Pseudo Code 1/3

- Given: a sentence of length n
- Matrix ϑ storing highest reachability probabilites
- Matrix ψ storing contributing states for reachability
- Initialization:

```
for all states i do
        $\vartheta_1(i) = \pi_i * B_{i1}$
        $\psi_1(i) = 0$
end
```

Viterbi Algorithm - Pseudo Code 2/3

- Induction:

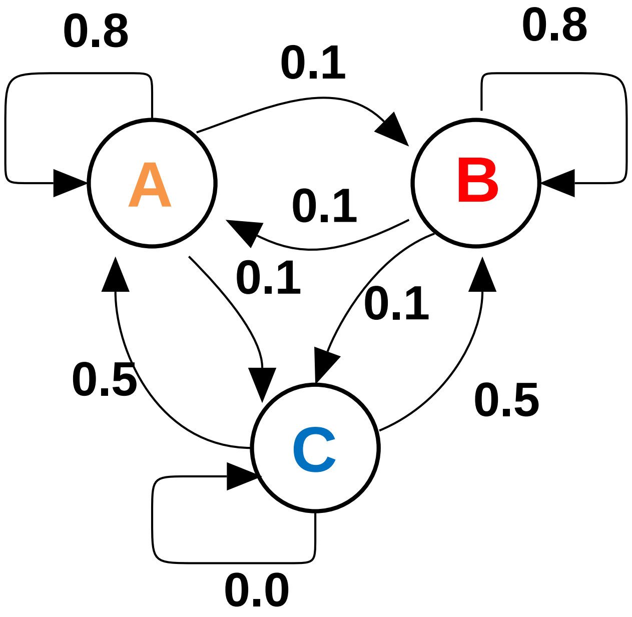
```
for t := 2 to n step 1 do
        for all states i do
                $\vartheta_t(i) = B_{it} * \max_{1 \leq j \leq |S|} \left(A_{ji} * \vartheta_{t-1}(i)\right)$
                $\psi_t(i) = \arg \max_{1 \leq j \leq |S|} \left(A_{ji} * \vartheta_{t-1}(i)\right)$
        end
end
```

Viterbi Algorithm - Pseudo Code 3/3

- Termination and path-readout:

```
$y_T = \arg \max_{1≤j≤|S|} (\vartheta_T(j))$
for j := n to 1 step -1 do
        $y_t = \psi_{t+1}(y_{t+1})$
end
$P(y_1, \dots, y_T) = \max_{1≤j≤|S|} (\vartheta_n(j))$
```

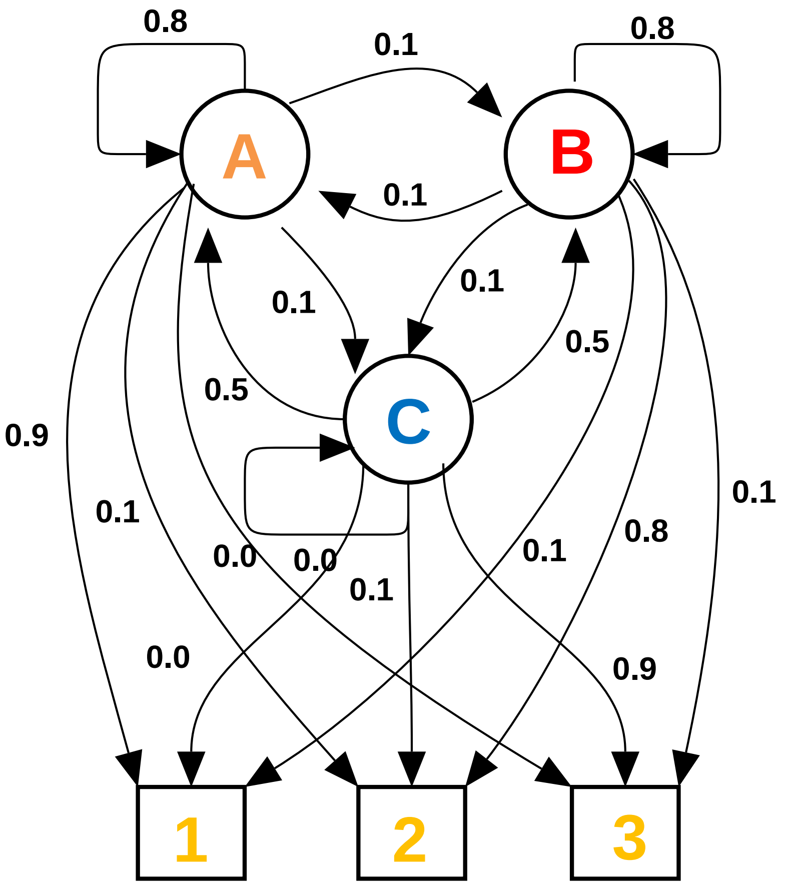
Experiment



N=55

```
AAAAAABBBCBBBBBBCBCAAAAAABBBBBAAABBBBAAAAAAACAAAAAAAAAA
1111111223222222323111112322231112222121111131221211111
```

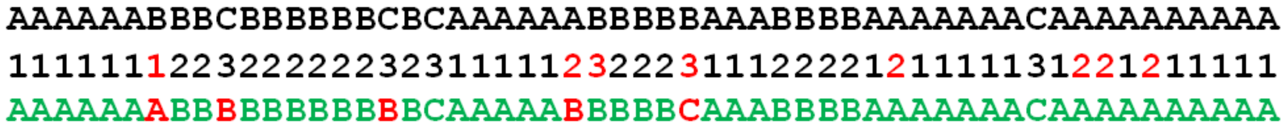
Experiment - Used Sequence



	1	2	3
A	0.9	0.1	0.0
B	0.1	0.8	0.1
C	0.0	0.1	0.9

```
AAAAAABBBCBBBBBBCBCAAAAAABBBBBAAABBBBAAAAAAACAAAAAAAAAA
1111111223222222323111112322231112222121111131221211111
```

Experiment - Recreated Sequence



```
AAAAAABBBCBBBBBBCBCAAAAAABBBBBAAABBBBAAAAAAACAAAAAAAAAA
1111111223222222323111112322231112222121111131221211111
AAAAAAABBBBBBBBBBBCAAAAABBBBBCAAABBBBAAAAAAACAAAAAAAAAA
```

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Summary

- Applying viterbi algorithm in real time case.
- We observe the relation between true state and hidden state.
- We also observe the downside of the algorithm.
- Student travelling between rooms.
- Use result for analyzing and reducing error.

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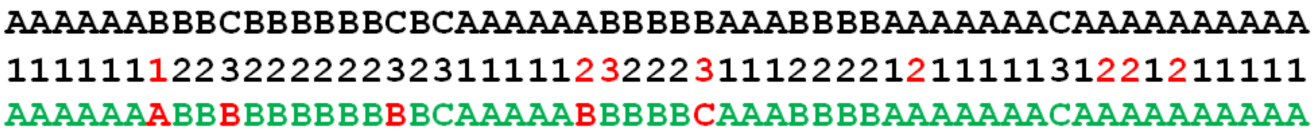

```
AAAAAABBBCBBBBBBCBCAAAAAABBBBBAAABBBBAAAAAAACAAAAAAAAAA
1111111223222222323111112322231112222121111131221211111
AAAAAAABBBBBBBBBBBCAAAAABBBBBCAAABBBBAAAAAAACAAAAAAAAAA
```

Questions?

Sources

- Pseudo Code: kontext.fraunhofer.de/haenelt/kurs/folien/Haenelt_Viterbi-Algorithmus.pdf
- Used Images: https://forschung.bissantz.de/hidden-markov-modelle-so-bekommt-man-zustaende
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