



Hidden Markov Models

Natural Language Processing: Jordan
Boyd-Graber

University of Colorado Boulder

LECTURE 20

Decoding Sentence 1

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{answer}_0 & \text{the}_1 & \text{question}_2 \end{pmatrix} \quad (1)$$

Decoding Sentence 1

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{answer}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} \text{VB} \\ \text{DET} \\ \text{PRO} \\ \text{NN} \end{matrix} & \left(\begin{matrix} 0.00 \\ \\ \\ \end{matrix} \right) \end{matrix} \quad (1)$$

Decoding Sentence 1

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{answer}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ 0.00 \\ 0.00 \end{pmatrix} \quad (1)$$

Decoding Sentence 1

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{answer}} = 0.00 + 0.00 = \textcolor{red}{0.00}$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 \\ 0.00 \\ \textcolor{red}{0.00} \\ \end{matrix} \right) \end{matrix} \quad (1)$$

Decoding Sentence 1

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{answer}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 \\ 0.00 \\ 0.00 \\ 0.00 \end{matrix} \right) \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_0(VB) + w_{VB, VB} + w_{VB, the} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & \\ 0.00 & 0.00 & \\ 0.00 & 0.00 & \\ 0.00 & 0.00 & \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_0(VB) + w_{VB, DET} + w_{DET, the} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_0(VB) + w_{VB, PRO} + w_{PRO, the} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \end{matrix} \right) \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_0(VB) + w_{VB, NN} + w_{NN, the} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \\ 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_1(VB) + w_{VB, VB} + w_{VB, question} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_1(VB) + w_{VB, DET} + w_{DET, question} = 0.00 + 0.00 + 0.00 = \textcolor{red}{0.00}$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & \textcolor{red}{0.00} \\ 0.00 & 0.00 & \\ 0.00 & 0.00 & \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_1(VB) + w_{VB, PRO} + w_{PRO, question} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

$$\delta_1(VB) + w_{VB, NN} + w_{NN, \text{question}} = 0.00 + 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

Decoding Sentence 1

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} VB & VB \\ VB & VB \\ VB & VB \\ VB & VB \end{pmatrix} \end{matrix} \quad (2)$$

Decoding Sentence 1

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} VB & VB \\ VB & VB \\ VB & VB \\ VB & VB \end{pmatrix} \end{matrix} \quad (2)$$

Decoding Sentence 1

- Scores

$$\delta = \begin{matrix} & \text{answer}_0 & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 \end{pmatrix} \end{matrix} \quad (1)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{question}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} VB & VB \\ VB & VB \\ VB & VB \\ VB & VB \end{pmatrix} \end{matrix} \quad (2)$$

- Reconstruction: VB VB VB

- Correct answer: VB DET NN
- Prediction: VB VB VB

- Correct answer: VB DET NN
- Prediction: VB VB VB

- Correct answer: VB DET NN
- Prediction: VB VB VB

Gold Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, question)

Shared Features

(START, VB)
(VB, answer)

Predicted Features

(VB, the)
(VB, question)
(VB, VB)

- Correct answer: VB DET NN
- Prediction: VB VB VB

Gold Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, question)

Shared Features

(START, VB)
(VB, answer)

Predicted Features

(VB, the)
(VB, question)
(VB, VB)

- New feature vector: (DET, NN): 1.00; (DET, the): 1.00;
(NN, question): 1.00; (VB, DET): 1.00; (VB, VB): -2.00;
(VB, question): -1.00; (VB, the): -1.00

- Correct answer: VB DET NN
- Prediction: VB VB VB

Gold Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, question)

Shared Features

(START, VB)
(VB, answer)

Predicted Features

(VB, the)
(VB, question)
(VB, VB)

- New feature vector: (DET, NN): 1.00; (DET, the): 1.00;
(NN, question): 1.00; (VB, DET): 1.00; (VB, VB): -2.00;
(VB, question): -1.00; (VB, the): -1.00

Decoding Sentence 2

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ & & & \end{pmatrix} \quad (3)$$

Decoding Sentence 2

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{question}} = 0.00 + -1.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} -1.00 \\ & & \end{matrix} \right) \end{matrix} \quad (3)$$

Decoding Sentence 2

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{question}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ -1.00 \\ 0.00 \\ \end{pmatrix} \quad (3)$$

Decoding Sentence 2

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{question}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 \\ 0.00 \\ 0.00 \\ \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{question}} = 0.00 + 1.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 \\ 0.00 \\ 0.00 \\ 1.00 \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_0(NN) + w_{NN, VB} + w_{VB, the} = 1.00 + 0.00 + -1.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 1.00 \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_0(NN) + w_{NN, DET} + w_{DET, the} = 1.00 + 0.00 + 1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 \\ 0.00 & 2.00 \\ 0.00 & \\ 1.00 & \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_0(NN) + w_{NN, PRO} + w_{PRO, the} = 1.00 + 0.00 + 0.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 \\ 0.00 & 2.00 \\ 0.00 & 1.00 \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_0(DET) + w_{DET, NN} + w_{NN, the} = 0.00 + 1.00 + 0.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & \\ 0.00 & 2.00 & \\ 0.00 & 1.00 & \\ 1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_1(DET) + w_{DET, VB} + w_{VB, answer} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & \\ 0.00 & 1.00 & \\ 1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_1(DET) + w_{\text{DET}, \text{DET}} + w_{\text{DET}, \text{answer}} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & \\ 1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_1(DET) + w_{DET, PRO} + w_{PRO, answer} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

$$\delta_1(DET) + w_{DET, NN} + w_{NN, answer} = 2.00 + 1.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 3.00 \end{pmatrix} \end{matrix} \quad (3)$$

Decoding Sentence 2

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 3.00 \end{pmatrix} \end{matrix} \quad (3)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} NN & DET \\ NN & DET \\ NN & DET \\ DET & DET \end{pmatrix} \end{matrix} \quad (4)$$

Decoding Sentence 2

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 3.00 \end{pmatrix} \end{matrix} \quad (3)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} NN & DET \\ \textcolor{red}{NN} & DET \\ NN & DET \\ DET & \textcolor{red}{DET} \end{pmatrix} \end{matrix} \quad (4)$$

Decoding Sentence 2

- Scores

$$\delta = \begin{matrix} & \text{question}_0 & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 0.00 & 2.00 \\ 0.00 & 2.00 & 2.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 3.00 \end{pmatrix} \end{matrix} \quad (3)$$

- Backpointers

$$\beta = \begin{matrix} & \text{the}_1 & \text{answer}_2 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} NN & DET \\ NN & DET \\ NN & DET \\ DET & DET \end{pmatrix} \end{matrix} \quad (4)$$

- Reconstruction: NN DET NN

- Correct answer: VB DET NN
- Prediction: NN DET NN

- Correct answer: VB DET NN
- Prediction: **NN** DET NN

- Correct answer: VB DET NN
- Prediction: NN DET NN

Gold Features

(VB, DET)
(START, VB)
(VB, question)

Shared Features

(DET, the)
(DET, NN)
(NN, answer)

Predicted Features

(START, NN)
(NN, question)
(NN, DET)

- Correct answer: VB DET NN
- Prediction: NN DET NN

Gold Features

(VB, DET)
(START, VB)
(VB, question)

Shared Features

(DET, the)
(DET, NN)
(NN, answer)

Predicted Features

(START, NN)
(NN, question)
(NN, DET)

- New feature vector: (DET, NN): 1.00; (DET, the): 1.00;
(NN, DET): -1.00; (VB, DET): 2.00; (VB, VB): -2.00; (VB, the):
-1.00; (START, NN): -1.00; (START, VB): 1.00

- Correct answer: VB DET NN
- Prediction: NN DET NN

Gold Features

(VB, DET)
(START, VB)
(VB, question)

Shared Features

(DET, the)
(DET, NN)
(NN, answer)

Predicted Features

(START, NN)
(NN, question)
(NN, DET)

- New feature vector: (DET, NN): 1.00; (DET, the): 1.00;
(NN, DET): -1.00; (VB, DET): 2.00; (VB, VB): -2.00; (VB, the):
-1.00; (START, NN): -1.00; (START, VB): 1.00

Decoding Sentence 3

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \end{pmatrix} \quad (5)$$

Decoding Sentence 3

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{you}} = 1.00 + 0.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} \text{VB} \\ \text{DET} \\ \text{PRO} \\ \text{NN} \end{matrix} & \begin{pmatrix} 1.00 \\ \\ \\ \end{pmatrix} & & & \end{matrix} \quad (5)$$

Decoding Sentence 3

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{you}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 1.00 \\ 0.00 \\ \\ \end{pmatrix} \end{matrix} \quad (5)$$

Decoding Sentence 3

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{you}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 1.00 \\ 0.00 \\ 0.00 \\ \end{pmatrix} \end{matrix} \quad (5)$$

Decoding Sentence 3

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{you}} = -1.00 + 0.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 \\ 0.00 \\ 0.00 \\ -1.00 \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_0(DET) + w_{DET, VB} + w_{VB, demand} = 0.00 + 0.00 + 0.00 = \textcolor{red}{0.00}$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & \textcolor{red}{0.00} & & \\ 0.00 & & & \\ 0.00 & & & \\ -1.00 & & & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_0(VB) + w_{VB, DET} + w_{DET, demand} = 1.00 + 2.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 \\ 0.00 & 3.00 \\ 0.00 & \\ -1.00 & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_0(VB) + w_{VB, PRO} + w_{PRO, demand} = 1.00 + 0.00 + 0.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 \\ 0.00 & 3.00 \\ 0.00 & \textcolor{red}{1.00} \\ -1.00 & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_0(VB) + w_{VB, NN} + w_{NN, demand} = 1.00 + 0.00 + 0.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 \\ 0.00 & 3.00 \\ 0.00 & 1.00 \\ -1.00 & \textcolor{red}{1.00} \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_1(DET) + w_{DET, VB} + w_{VB, the} = 3.00 + 0.00 + -1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 & \\ 0.00 & 3.00 & & \\ 0.00 & 1.00 & & \\ -1.00 & 1.00 & & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_1(DET) + w_{DET, DET} + w_{DET, the} = 3.00 + 0.00 + 1.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 \\ 0.00 & 3.00 & 4.00 \\ 0.00 & 1.00 \\ -1.00 & 1.00 \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_1(DET) + w_{DET, PRO} + w_{PRO, the} = 3.00 + 0.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 \\ 0.00 & 3.00 & 4.00 \\ 0.00 & 1.00 & 3.00 \\ -1.00 & 1.00 \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_1(DET) + w_{DET, NN} + w_{NN, the} = 3.00 + 1.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 \\ 0.00 & 3.00 & 4.00 \\ 0.00 & 1.00 & 3.00 \\ -1.00 & 1.00 & 4.00 \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_2(DET) + w_{DET, VB} + w_{VB, delay} = 4.00 + 0.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & \\ 0.00 & 1.00 & 3.00 & \\ -1.00 & 1.00 & 4.00 & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_2(VB) + w_{VB, DET} + w_{DET, delay} = 2.00 + 2.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & \\ -1.00 & 1.00 & 4.00 & \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_2(DET) + w_{DET, PRO} + w_{PRO, delay} = 4.00 + 0.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & 4.00 \\ -1.00 & 1.00 & 4.00 & 4.00 \end{matrix} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

$$\delta_2(DET) + w_{DET, NN} + w_{NN, delay} = 4.00 + 1.00 + 0.00 = 5.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{array}{cccc} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & 4.00 \\ -1.00 & 1.00 & 4.00 & 5.00 \end{array} \right) \end{matrix} \quad (5)$$

Decoding Sentence 3

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & 4.00 \\ -1.00 & 1.00 & 4.00 & 5.00 \end{pmatrix} \end{matrix} \quad (5)$$

- Backpointers

$$\beta = \begin{matrix} & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} DET & DET & DET \\ VB & DET & VB \\ VB & DET & DET \\ VB & DET & DET \end{pmatrix} \end{matrix} \quad (6)$$

Decoding Sentence 3

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & 4.00 \\ -1.00 & 1.00 & 4.00 & 5.00 \end{pmatrix} \end{matrix} \quad (5)$$

- Backpointers

$$\beta = \begin{matrix} & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} DET & DET & DET \\ VB & DET & VB \\ VB & DET & DET \\ VB & DET & DET \end{pmatrix} \end{matrix} \quad (6)$$

Decoding Sentence 3

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{array}{cccc} 1.00 & 0.00 & 2.00 & 4.00 \\ 0.00 & 3.00 & 4.00 & 4.00 \\ 0.00 & 1.00 & 3.00 & 4.00 \\ -1.00 & 1.00 & 4.00 & 5.00 \end{array} \right) \end{matrix} \quad (5)$$

- Backpointers

$$\beta = \begin{matrix} & \text{demand}_1 & \text{the}_2 & \text{delay}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{array}{ccc} DET & DET & DET \\ VB & DET & VB \\ VB & DET & DET \\ VB & DET & DET \end{array} \right) \end{matrix} \quad (6)$$

- Reconstruction: VB DET DET NN

- Correct answer: PRO VB DET NN
- Prediction: VB DET DET NN

- Correct answer: PRO VB DET NN
- Prediction: VB DET DET NN

- Correct answer: PRO VB DET NN
- Prediction: VB DET DET NN

Gold Features

(VB, demand)
(PRO, you)
(START, PRO)
(PRO, VB)

Shared Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, delay)

Predicted Features

(DET, DET)
(START, VB)
(DET, demand)
(VB, you)

- Correct answer: PRO VB DET NN
- Prediction: VB DET DET NN

Gold Features

(VB, demand)
(PRO, you)
(START, PRO)
(PRO, VB)

Shared Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, delay)

Predicted Features

(DET, DET)
(START, VB)
(DET, demand)
(VB, you)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00;
(DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00;
(PRO, VB): 1.00; (PRO, you): 1.00; (VB, DET): 2.00; (VB, VB):
-2.00; (VB, demand): 1.00; (VB, the): -1.00; (VB, you): -1.00;
(START, NN): -1.00; (START, PRO): 1.00

- Correct answer: PRO VB DET NN
- Prediction: VB DET DET NN

Gold Features

(VB, demand)
(PRO, you)
(START, PRO)
(PRO, VB)

Shared Features

(DET, the)
(DET, NN)
(VB, DET)
(NN, delay)

Predicted Features

(DET, DET)
(START, VB)
(DET, demand)
(VB, you)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00;
(DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00;
(PRO, VB): 1.00; (PRO, you): 1.00; (VB, DET): 2.00; (VB, VB):
-2.00; (VB, demand): 1.00; (VB, the): -1.00; (VB, you): -1.00;
(START, NN): -1.00; (START, PRO): 1.00

Decoding Sentence 4

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \end{pmatrix} \quad (7)$$

Decoding Sentence 4

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{you}} = 0.00 + -1.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} \text{VB} \\ \text{DET} \\ \text{PRO} \\ \text{NN} \end{matrix} \begin{pmatrix} \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ -1.00 & & & \end{pmatrix} \quad (7)$$

Decoding Sentence 4

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{you}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ -1.00 \\ 0.00 \\ \end{pmatrix} \quad (7)$$

Decoding Sentence 4

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{you}} = 1.00 + 1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ -1.00 \\ 0.00 \\ 2.00 \\ \end{pmatrix} \quad (7)$$

Decoding Sentence 4

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{you}} = -1.00 + 0.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} -1.00 \\ 0.00 \\ 2.00 \\ -1.00 \end{matrix} \right) \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_0(PRO) + w_{PRO, VB} + w_{VB, delay} = 2.00 + 1.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & & \\ 0.00 & & & \\ 2.00 & & & \\ -1.00 & & & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_0(PRO) + w_{PRO, DET} + w_{DET, delay} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} -1.00 & 3.00 \\ 0.00 & 2.00 \\ 2.00 & \\ -1.00 & \end{matrix} \right) \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_0(\textit{PRO}) + w_{\textit{PRO}, \textit{PRO}} + w_{\textit{PRO}, \textit{delay}} = 2.00 + 0.00 + 0.00 = \textcolor{red}{2.00}$$

- Scores

$$\delta = \begin{matrix} & \textit{you}_0 & \textit{delay}_1 & \textit{the}_2 & \textit{demand}_3 \\ \begin{matrix} \textit{VB} \\ \textit{DET} \\ \textit{PRO} \\ \textit{NN} \end{matrix} & \left(\begin{array}{cccc} -1.00 & 3.00 & & \\ 0.00 & 2.00 & & \\ 2.00 & \textcolor{red}{2.00} & & \\ -1.00 & & & \end{array} \right) \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_0(PRO) + w_{PRO, NN} + w_{NN, delay} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 \\ 0.00 & 2.00 \\ 2.00 & 2.00 \\ -1.00 & 2.00 \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_1(PRO) + w_{PRO, VB} + w_{VB, the} = 2.00 + 1.00 + -1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & \\ 0.00 & 2.00 & & \\ 2.00 & 2.00 & & \\ -1.00 & 2.00 & & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_1(VB) + w_{VB, DET} + w_{DET, the} = 3.00 + 2.00 + 1.00 = 6.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 \\ 0.00 & 2.00 & 6.00 \\ 2.00 & 2.00 & \\ -1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_1(VB) + w_{VB, PRO} + w_{PRO, the} = 3.00 + 0.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} -1.00 & 3.00 & 2.00 \\ 0.00 & 2.00 & 6.00 \\ 2.00 & 2.00 & 3.00 \\ -1.00 & 2.00 & \end{matrix} \right) \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_1(VB) + w_{VB, NN} + w_{NN, the} = 3.00 + 0.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 \\ 0.00 & 2.00 & 6.00 \\ 2.00 & 2.00 & 3.00 \\ -1.00 & 2.00 & 3.00 \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_2(DET) + w_{DET, VB} + w_{VB, demand} = 6.00 + 0.00 + 1.00 = 7.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & \\ 2.00 & 2.00 & 3.00 & \\ -1.00 & 2.00 & 3.00 & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_2(DET) + w_{DET, DET} + w_{DET, demand} = \\ 6.00 + -1.00 + -1.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & \\ -1.00 & 2.00 & 3.00 & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_2(DET) + w_{DET, PRO} + w_{PRO, demand} = 6.00 + 0.00 + 0.00 = 6.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & 6.00 \\ -1.00 & 2.00 & 3.00 & \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

$$\delta_2(DET) + w_{DET, NN} + w_{NN, demand} = 6.00 + 1.00 + 0.00 = 7.00$$

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & 6.00 \\ -1.00 & 2.00 & 3.00 & 7.00 \end{pmatrix} \end{matrix} \quad (7)$$

Decoding Sentence 4

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & 6.00 \\ -1.00 & 2.00 & 3.00 & 7.00 \end{pmatrix} \end{matrix} \quad (7)$$

- Backpointers

$$\beta = \begin{matrix} & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & DET \\ PRO & VB & DET \\ PRO & VB & DET \\ PRO & VB & DET \end{pmatrix} \end{matrix} \quad (8)$$

Decoding Sentence 4

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & 6.00 \\ -1.00 & 2.00 & 3.00 & 7.00 \end{pmatrix} \end{matrix} \quad (7)$$

- Backpointers

$$\beta = \begin{matrix} & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & DET \\ PRO & VB & DET \\ PRO & VB & DET \\ PRO & VB & DET \end{pmatrix} \end{matrix} \quad (8)$$

Decoding Sentence 4

- Scores

$$\delta = \begin{matrix} & \text{you}_0 & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} -1.00 & 3.00 & 2.00 & 7.00 \\ 0.00 & 2.00 & 6.00 & 4.00 \\ 2.00 & 2.00 & 3.00 & 6.00 \\ -1.00 & 2.00 & 3.00 & 7.00 \end{pmatrix} \end{matrix} \quad (7)$$

- Backpointers

$$\beta = \begin{matrix} & \text{delay}_1 & \text{the}_2 & \text{demand}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & DET \\ PRO & VB & DET \\ PRO & VB & DET \\ PRO & VB & DET \end{pmatrix} \end{matrix} \quad (8)$$

- Reconstruction: PRO VB DET VB

- Correct answer: PRO VB DET NN
- Prediction: PRO VB DET VB

- Correct answer: PRO VB DET NN
- Prediction: PRO VB DET VB

- Correct answer: PRO VB DET NN
- Prediction: PRO VB DET VB

Gold Features

(DET, NN)
(NN, demand)

Shared Features

(VB, delay)
(DET, the)
(VB, DET)
(PRO, you)
(START, PRO)
(PRO, VB)

Predicted Features

(DET, VB)
(VB, demand)

- Correct answer: PRO VB DET NN
- Prediction: PRO VB DET VB

Gold Features

(DET, NN)
(NN, demand)

Shared Features

(VB, delay)
(DET, the)
(VB, DET)
(PRO, you)
(START, PRO)
(PRO, VB)

Predicted Features

(DET, VB)
(VB, demand)

- New feature vector: (DET, DET): -1.00; (DET, NN): 2.00; (DET, VB): -1.00; (DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00; (NN, demand): 1.00; (PRO, VB): 1.00; (PRO, you): 1.00; (VB, DET): 2.00; (VB, VB): -2.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00

- Correct answer: PRO VB DET NN
- Prediction: PRO VB DET VB

Gold Features

(DET, NN)
(NN, demand)

Shared Features

(VB, delay)
(DET, the)
(VB, DET)
(PRO, you)
(START, PRO)
(PRO, VB)

Predicted Features

(DET, VB)
(VB, demand)

- New feature vector: (DET, DET): -1.00; (DET, NN): 2.00; (DET, VB): -1.00; (DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00; (NN, demand): 1.00; (PRO, VB): 1.00; (PRO, you): 1.00; (VB, DET): 2.00; (VB, VB): -2.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00

Decoding Sentence 5

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \end{pmatrix} \quad (9)$$

Decoding Sentence 5

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{what}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} \text{VB} \\ \text{DET} \\ \text{PRO} \\ \text{NN} \end{matrix} \begin{pmatrix} \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ 0.00 & & & \end{pmatrix} \quad (9)$$

Decoding Sentence 5

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{what}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ 0.00 & & & \\ 0.00 & & & \\ & & & \\ & & & \end{pmatrix} \quad (9)$$

Decoding Sentence 5

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{what}} = 1.00 + 0.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 \\ 0.00 \\ 1.00 \\ \end{matrix} \right) \end{matrix} \quad (9)$$

Decoding Sentence 5

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{what}} = -1.00 + 0.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ -1.00 \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_0(PRO) + w_{PRO, VB} + w_{VB, \text{silence}} = 1.00 + 1.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ -1.00 \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_0(VB) + w_{VB, DET} + w_{DET, \text{silence}} = 0.00 + 2.00 + 0.00 = \textcolor{red}{2.00}$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 & 2.00 & & \\ 0.00 & \textcolor{red}{2.00} & & \\ 1.00 & & & \\ -1.00 & & & \end{matrix} \right) \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_0(PRO) + w_{PRO, PRO} + w_{PRO, \text{silence}} = 1.00 + 0.00 + 0.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{array}{cccc} 0.00 & 2.00 & & \\ 0.00 & 2.00 & & \\ 1.00 & \textcolor{red}{1.00} & & \\ -1.00 & & & \end{array} \right) \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_0(DET) + w_{DET, NN} + w_{NN, silence} = 0.00 + 2.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 & 2.00 & & \\ 0.00 & 2.00 & & \\ 1.00 & 1.00 & & \\ -1.00 & 2.00 & & \end{matrix} \right) \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_1(PRO) + w_{PRO, VB} + w_{VB, can} = 1.00 + 1.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & \\ 0.00 & 2.00 & & \\ 1.00 & 1.00 & & \\ -1.00 & 2.00 & & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_1(VB) + w_{VB, DET} + w_{DET, can} = 2.00 + 2.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 \\ 0.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & \\ -1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_1(VB) + w_{VB, PRO} + w_{PRO, can} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 \\ 0.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 \\ -1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_1(DET) + w_{DET, NN} + w_{NN, can} = 2.00 + 2.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 \\ 0.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 \\ -1.00 & 2.00 & 4.00 \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_2(NN) + w_{NN, VB} + w_{VB, show} = 4.00 + 0.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & \\ 1.00 & 1.00 & 2.00 & \\ -1.00 & 2.00 & 4.00 & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_2(VB) + w_{VB, DET} + w_{DET, show} = 2.00 + 2.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & \\ -1.00 & 2.00 & 4.00 & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_2(DET) + w_{DET, PRO} + w_{PRO, show} = 4.00 + 0.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 4.00 \\ -1.00 & 2.00 & 4.00 & \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

$$\delta_2(DET) + w_{DET, NN} + w_{NN, show} = 4.00 + 2.00 + 0.00 = 6.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 4.00 \\ -1.00 & 2.00 & 4.00 & 6.00 \end{pmatrix} \end{matrix} \quad (9)$$

Decoding Sentence 5

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 4.00 \\ -1.00 & 2.00 & 4.00 & 6.00 \end{pmatrix} \end{matrix} \quad (9)$$

- Backpointers

$$\beta = \begin{matrix} & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & NN \\ VB & VB & VB \\ PRO & VB & DET \\ DET & DET & DET \end{pmatrix} \end{matrix} \quad (10)$$

Decoding Sentence 5

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 4.00 \\ -1.00 & 2.00 & 4.00 & 6.00 \end{pmatrix} \end{matrix} \quad (9)$$

- Backpointers

$$\beta = \begin{matrix} & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & NN \\ VB & VB & VB \\ PRO & VB & DET \\ DET & DET & DET \end{pmatrix} \end{matrix} \quad (10)$$

Decoding Sentence 5

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 2.00 & 4.00 \\ 0.00 & 2.00 & 4.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 4.00 \\ -1.00 & 2.00 & 4.00 & 6.00 \end{pmatrix} \end{matrix} \quad (9)$$

- Backpointers

$$\beta = \begin{matrix} & \text{silence}_1 & \text{can}_2 & \text{show}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & PRO & NN \\ VB & VB & VB \\ PRO & VB & DET \\ DET & DET & DET \end{pmatrix} \end{matrix} \quad (10)$$

- Reconstruction: PRO VB DET NN

- Correct answer: PRO NN VB VB
- Prediction: PRO VB DET NN

- Correct answer: PRO NN VB VB
- Prediction: PRO VB DET NN

- Correct answer: PRO NN VB VB
- Prediction: PRO VB DET NN

Gold Features

(VB, show)
(VB, can)
(PRO, NN)
(NN, silence)
(NN, VB) (VB, VB)

Shared Features

(START, PRO)
(PRO, what)

Predicted Features

(DET, can)
(NN, show)
(VB, silence)
(DET, NN)
(VB, DET)
(PRO, VB)

- Correct answer: PRO NN VB VB
- Prediction: PRO VB DET NN

Gold Features

(VB, show)
 (VB, can)
 (PRO, NN)
 (NN, silence)
 (NN, VB) (VB, VB)

Shared Features

(START, PRO)
 (PRO, what)

Predicted Features

(DET, can)
 (NN, show)
 (VB, silence)
 (DET, NN)
 (VB, DET)
 (PRO, VB)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00; (DET, VB): -1.00; (DET, can): -1.00; (DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00; (NN, VB): 1.00; (NN, demand): 1.00; (NN, show): -1.00; (NN, silence): 1.00; (PRO, NN): 1.00; (PRO, you): 1.00; (VB, DET): 1.00; (VB, VB): -1.00; (VB, can): 1.00; (VB, show): 1.00; (VB, silence): -1.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00

- Correct answer: PRO NN VB VB
- Prediction: PRO VB DET NN

Gold Features

(VB, show)
 (VB, can)
 (PRO, NN)
 (NN, silence)
 (NN, VB) (VB, VB)

Shared Features

(START, PRO)
 (PRO, what)

Predicted Features

(DET, can)
 (NN, show)
 (VB, silence)
 (DET, NN)
 (VB, DET)
 (PRO, VB)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00; (DET, VB): -1.00; (DET, can): -1.00; (DET, demand): -1.00; (DET, the): 1.00; (NN, DET): -1.00; (NN, VB): 1.00; (NN, demand): 1.00; (NN, show): -1.00; (NN, silence): 1.00; (PRO, NN): 1.00; (PRO, you): 1.00; (VB, DET): 1.00; (VB, VB): -1.00; (VB, can): 1.00; (VB, show): 1.00; (VB, silence): -1.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00

Decoding Sentence 6

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \end{pmatrix} \quad (11)$$

Decoding Sentence 6

$$w_{\text{START}, \text{VB}} + w_{\text{VB}, \text{what}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} \text{VB} \\ \text{DET} \\ \text{PRO} \\ \text{NN} \end{matrix} \begin{pmatrix} \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ 0.00 & & & \end{pmatrix} \quad (11)$$

Decoding Sentence 6

$$w_{\text{START}, \text{DET}} + w_{\text{DET}, \text{what}} = 0.00 + 0.00 = 0.00$$

- Scores

$$\delta = \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} \begin{pmatrix} \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ 0.00 & & & \\ 0.00 & & & \\ & & & \\ & & & \end{pmatrix} \quad (11)$$

Decoding Sentence 6

$$w_{\text{START}, \text{PRO}} + w_{\text{PRO}, \text{what}} = 1.00 + 0.00 = 1.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 \\ 0.00 \\ 1.00 \\ \end{matrix} \right) \end{matrix} \quad (11)$$

Decoding Sentence 6

$$w_{\text{START}, \text{NN}} + w_{\text{NN}, \text{what}} = -1.00 + 0.00 = -1.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 \\ 0.00 \\ 1.00 \\ -1.00 \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_0(PRO) + w_{PRO, VB} + w_{VB, show} = 1.00 + 0.00 + 1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & & \\ 0.00 & & & \\ 1.00 & & & \\ -1.00 & & & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_0(VB) + w_{VB, DET} + w_{DET, show} = 0.00 + 1.00 + 0.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & & \\ 0.00 & \textcolor{red}{1.00} & & \\ 1.00 & & & \\ -1.00 & & & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_0(PRO) + w_{PRO, PRO} + w_{PRO, show} = 1.00 + 0.00 + 0.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{array}{cccc} 0.00 & 2.00 & & \\ 0.00 & 1.00 & & \\ 1.00 & \textcolor{red}{1.00} & & \\ -1.00 & & & \end{array} \right) \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_0(PRO) + w_{PRO, NN} + w_{NN, show} = 1.00 + 1.00 + -1.00 = \textcolor{red}{1.00}$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 & 2.00 \\ 0.00 & 1.00 \\ 1.00 & 1.00 \\ -1.00 & \textcolor{red}{1.00} \end{matrix} \right) \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_1(NN) + w_{NN, VB} + w_{VB, can} = 1.00 + 1.00 + 1.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & \\ 0.00 & 1.00 & & \\ 1.00 & 1.00 & & \\ -1.00 & 1.00 & & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_1(VB) + w_{VB, DET} + w_{DET, can} = 2.00 + 1.00 + -1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & \\ -1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_1(VB) + w_{VB, PRO} + w_{PRO, can} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 2.00 \\ -1.00 & 1.00 & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_1(VB) + w_{VB, NN} + w_{NN, \text{can}} = 2.00 + 0.00 + 0.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \left(\begin{matrix} 0.00 & 2.00 & 3.00 \\ 0.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 2.00 \\ -1.00 & 1.00 & 2.00 \end{matrix} \right) \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_2(NN) + w_{NN, VB} + w_{VB, \text{silence}} = 2.00 + 1.00 + -1.00 = 2.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & \\ 1.00 & 1.00 & 2.00 & \\ -1.00 & 1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_2(VB) + w_{VB, DET} + w_{DET, silence} = 3.00 + 1.00 + 0.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & \\ -1.00 & 1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_2(VB) + w_{VB, PRO} + w_{PRO, silence} = 3.00 + 0.00 + 0.00 = 3.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 3.00 \\ -1.00 & 1.00 & 2.00 & \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

$$\delta_2(VB) + w_{VB, NN} + w_{NN, \text{silence}} = 3.00 + 0.00 + 1.00 = 4.00$$

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 3.00 \\ -1.00 & 1.00 & 2.00 & 4.00 \end{pmatrix} \end{matrix} \quad (11)$$

Decoding Sentence 6

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 3.00 \\ -1.00 & 1.00 & 2.00 & 4.00 \end{pmatrix} \end{matrix} \quad (11)$$

- Backpointers

$$\beta = \begin{matrix} & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & NN & NN \\ VB & VB & VB \\ PRO & VB & VB \\ PRO & VB & VB \end{pmatrix} \end{matrix} \quad (12)$$

Decoding Sentence 6

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 3.00 \\ -1.00 & 1.00 & 2.00 & 4.00 \end{pmatrix} \end{matrix} \quad (11)$$

- Backpointers

$$\beta = \begin{matrix} & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & \textcolor{red}{NN} & NN \\ VB & VB & \textcolor{red}{VB} \\ PRO & VB & VB \\ \textcolor{red}{PRO} & VB & VB \end{pmatrix} \end{matrix} \quad (12)$$

Decoding Sentence 6

- Scores

$$\delta = \begin{matrix} & \text{what}_0 & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} 0.00 & 2.00 & 3.00 & 2.00 \\ 0.00 & 1.00 & 2.00 & 4.00 \\ 1.00 & 1.00 & 2.00 & 3.00 \\ -1.00 & 1.00 & 2.00 & 4.00 \end{pmatrix} \end{matrix} \quad (11)$$

- Backpointers

$$\beta = \begin{matrix} & \text{show}_1 & \text{can}_2 & \text{silence}_3 \\ \begin{matrix} VB \\ DET \\ PRO \\ NN \end{matrix} & \begin{pmatrix} PRO & NN & NN \\ VB & VB & VB \\ PRO & VB & VB \\ PRO & VB & VB \end{pmatrix} \end{matrix} \quad (12)$$

- Reconstruction: PRO NN VB DET

- Correct answer: PRO NN VB VB
- Prediction: PRO NN VB DET

- Correct answer: PRO NN VB VB
- Prediction: PRO NN VB DET

- Correct answer: PRO NN VB VB
- Prediction: PRO NN VB DET

Gold Features

(VB, silence)
(VB, VB)

Shared Features

(NN, show)
(VB, can)
(PRO, NN)
(NN, VB)
(START, PRO)
(PRO, what)

Predicted Features

(DET, silence)
(VB, DET)

- Correct answer: PRO NN VB VB
- Prediction: PRO NN VB DET

Gold Features

(VB, silence)
(VB, VB)

Shared Features

(NN, show)
(VB, can)
(PRO, NN)
(NN, VB)
(START, PRO)
(PRO, what)

Predicted Features

(DET, silence)
(VB, DET)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00; (DET, VB): -1.00; (DET, can): -1.00; (DET, demand): -1.00; (DET, silence): -1.00; (DET, the): 1.00; (NN, DET): -1.00; (NN, VB): 1.00; (NN, demand): 1.00; (NN, show): -1.00; (NN, silence): 1.00; (PRO, NN): 1.00; (PRO, you): 1.00; (VB, can): 1.00; (VB, show): 1.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00

- Correct answer: PRO NN VB VB
- Prediction: PRO NN VB DET

Gold Features

(VB, silence)
(VB, VB)

Shared Features

(NN, show)
(VB, can)
(PRO, NN)
(NN, VB)
(START, PRO)
(PRO, what)

Predicted Features

(DET, silence)
(VB, DET)

- New feature vector: (DET, DET): -1.00; (DET, NN): 1.00; (DET, VB): -1.00; (DET, can): -1.00; (DET, demand): -1.00; **(DET, silence): -1.00**; (DET, the): 1.00; (NN, DET): -1.00; (NN, VB): 1.00; (NN, demand): 1.00; (NN, show): -1.00; (NN, silence): 1.00; (PRO, NN): 1.00; (PRO, you): 1.00; (VB, can): 1.00; (VB, show): 1.00; (VB, the): -1.00; (VB, you): -1.00; (START, NN): -1.00; (START, PRO): 1.00