NLP Programming Tutorial 4 - Word Segmentation

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Introduction

What is Word Segmentation

- Sentences in Japanese or Chinese are written without spaces

単語分割を行う

- Word segmentation adds spaces between words

単語 分割 を 行 う

- For Japanese, there are tools like MeCab, KyTea

Tools Required: Substring

- In order to do word segmentation, we need to find substrings of a word

```
my_str = "hello world"

# Print the first 5 letters
print my_str[:5]
# Print all letters from position 6
print my_str[6:]
# Print all letters from position 3 until 7
print my_str[3:8]
```

```
$ ./my-program.py
hello
world
lo wo
```

Handling Unicode Characters with Substr

- The “unicode()” and “encode()” functions handle UTF-8

```
input_file = open("test_file.txt", "r")
for my_str in input_file:
    my_utf_str = unicode( my_str, "utf-8" )

    # Handle the string as a byte string
    print "str: %s %s" % (my_str[0:2], my_str[2:4])

    # Handle the string as a unicode string
    print "utf_str: %s %s" % (my_utf_str[0:2].encode("utf-8"),
                              my_utf_str[2:4].encode("utf-8"))
```

```
$ cat test_file.txt
単語分割
$ ./my-program.py
str: �� �
utf_str: 単語 分割
```

Word Segmentation is Hard!

- Many analyses for each sentence, only one correct

農産物価格安定法

O X

農産 物 価格 安定 法 | 農産 物価 格安 定法

(agricultural product price stabilization law) (agricultural cost of living discount measurement)

- How do we choose the correct analysis?

One Solution: Use a Language Model!

- Choose the analysis with the highest probability

P(農産 物 価格 安定 法)= $4.12*10^{-23}$

P(農産 物価 格安 定法) = $3.53*10^{-24}$

P(農産 物 価 格安 定法)= $6.53*10^{-25}$

P(農産 物 価格 安 定法)= $6.53*10^{-27}$

…

- Here, we will use a unigram language model

Problem: HUGE Number of Possibilities

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…
(how many?)

- How do we find the best answer **efficiently**?

This Man Has an Answer!

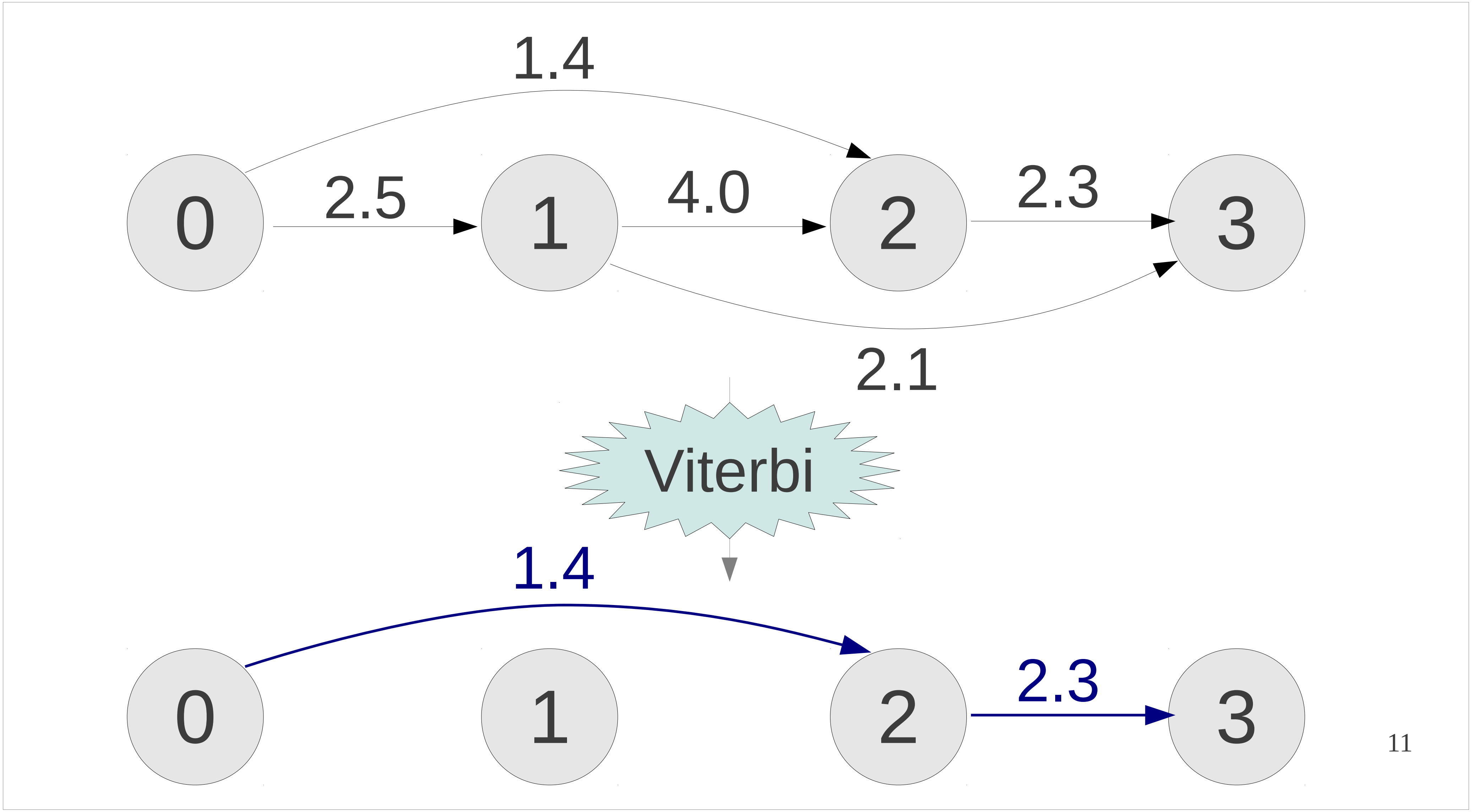
Andrew Viterbi

(Professor UCLA → Founder of Qualcomm)

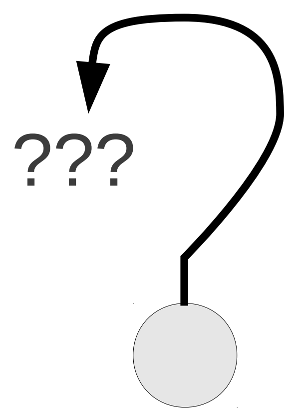
Viterbi Algorithm

The Viterbi Algorithm

- Efficient way to find the shortest path through a graph

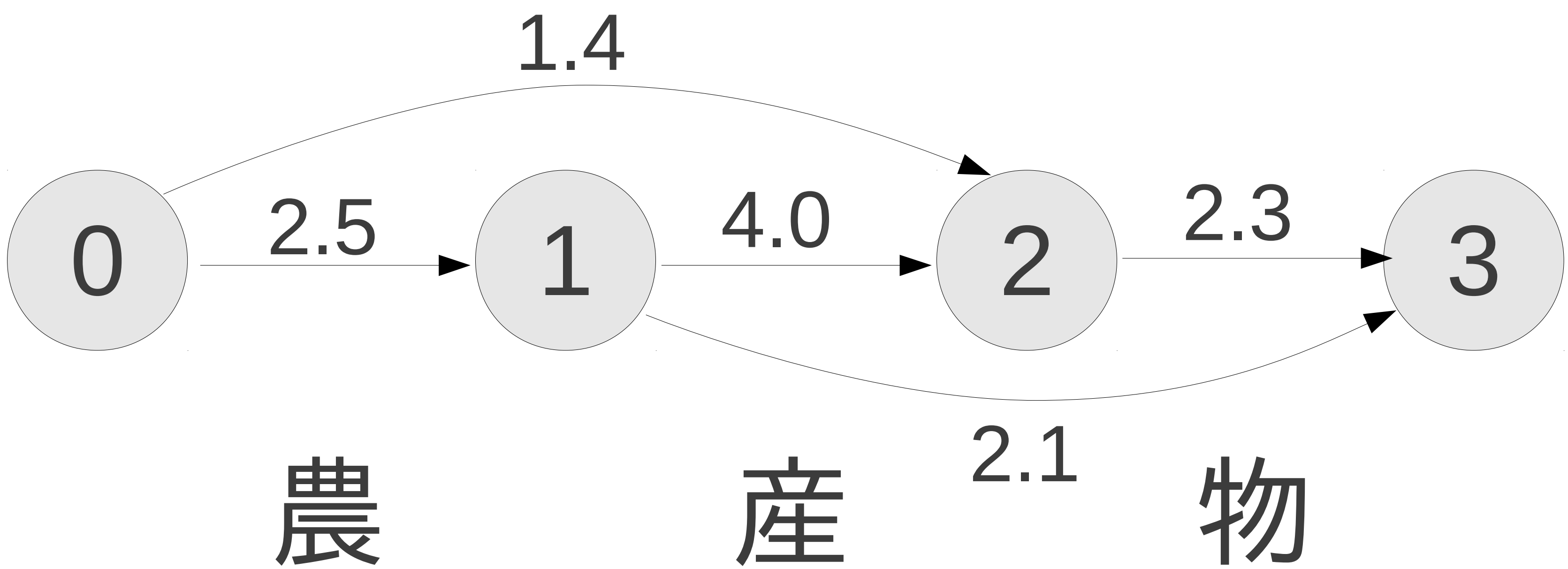


Graph?! What?!

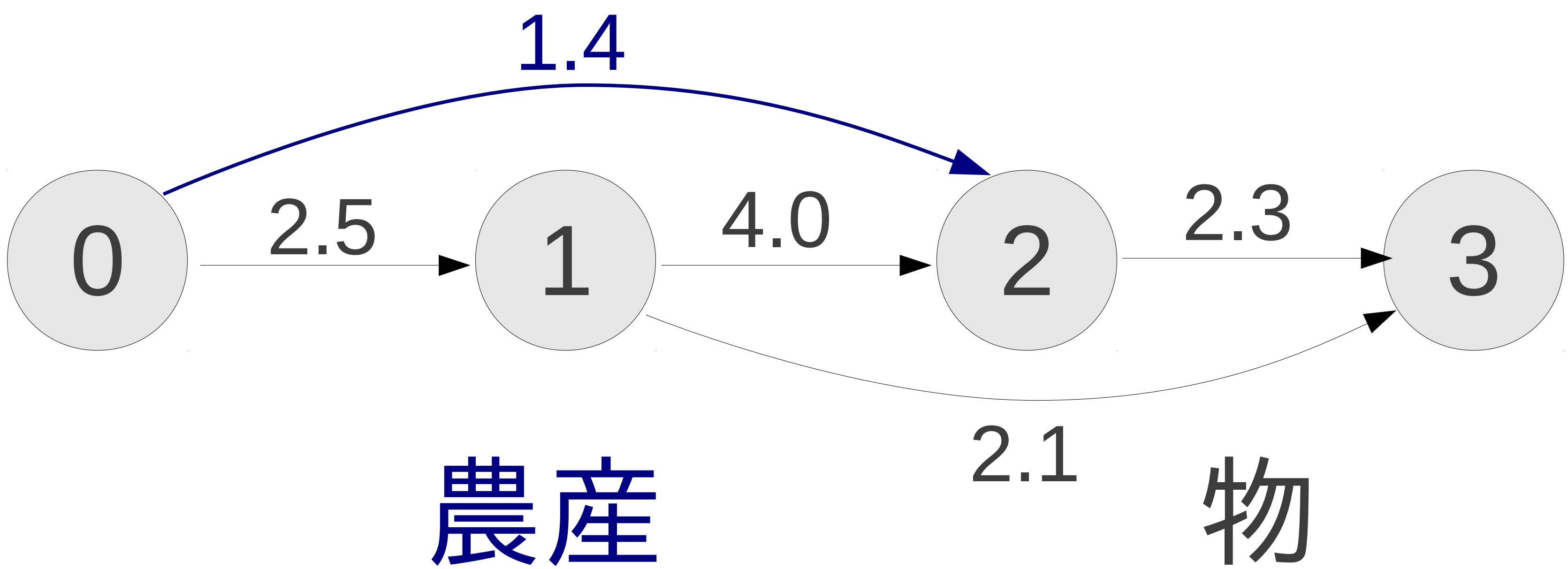


(Let Me Explain!)

Word Segmentations as Graphs

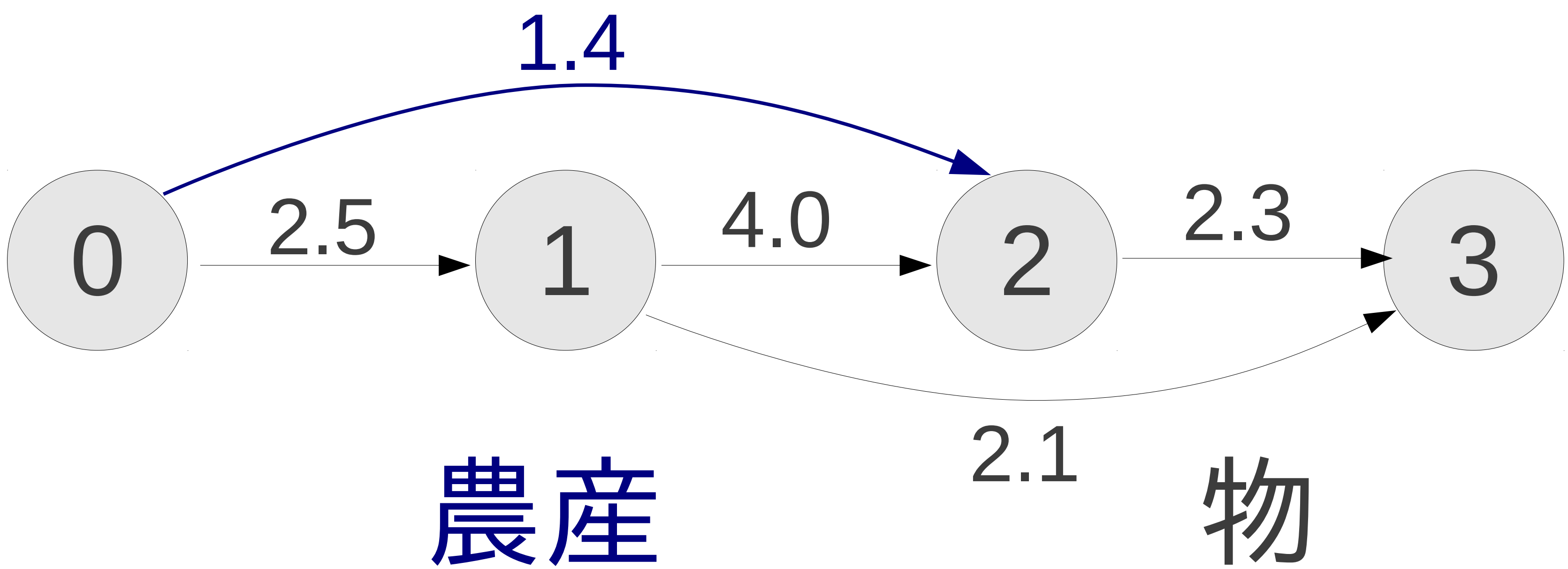


Word Segmentations as Graphs



- Each edge is a word

Word Segmentations as Graphs

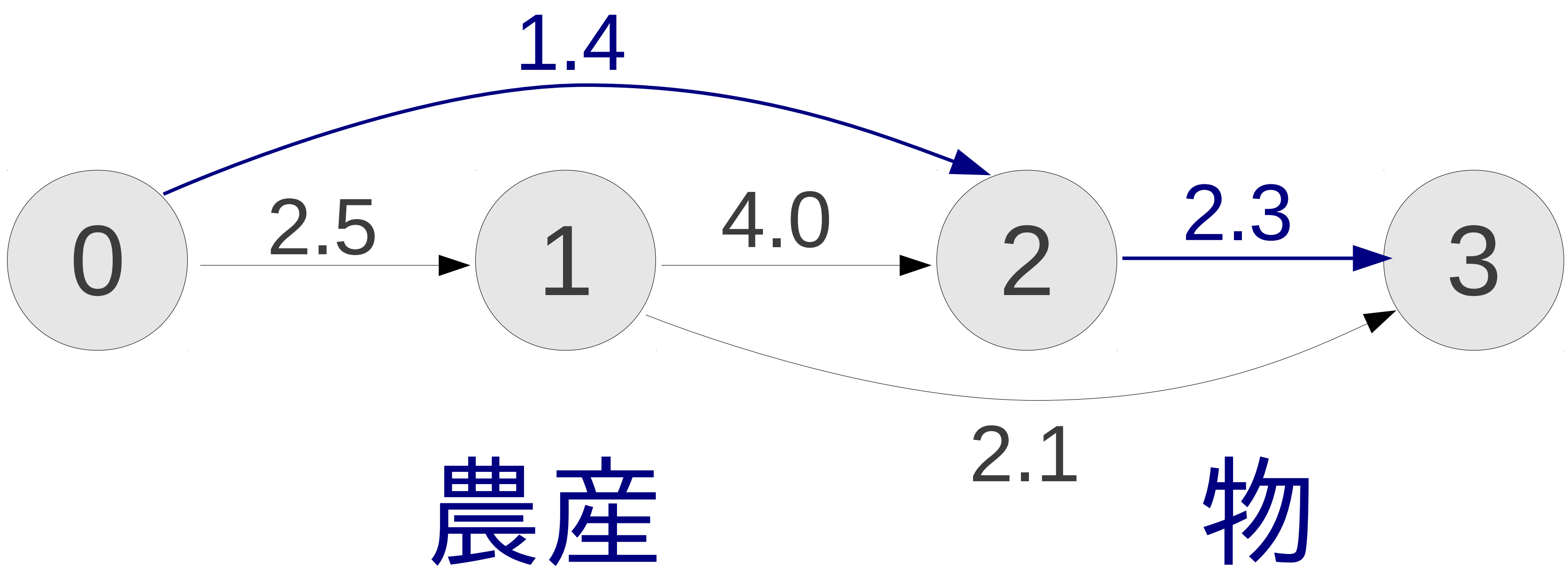


- Each edge is a word
- Each edge weight is a negative log probability

$$-\log(P(\text{農産})) = 1.4$$

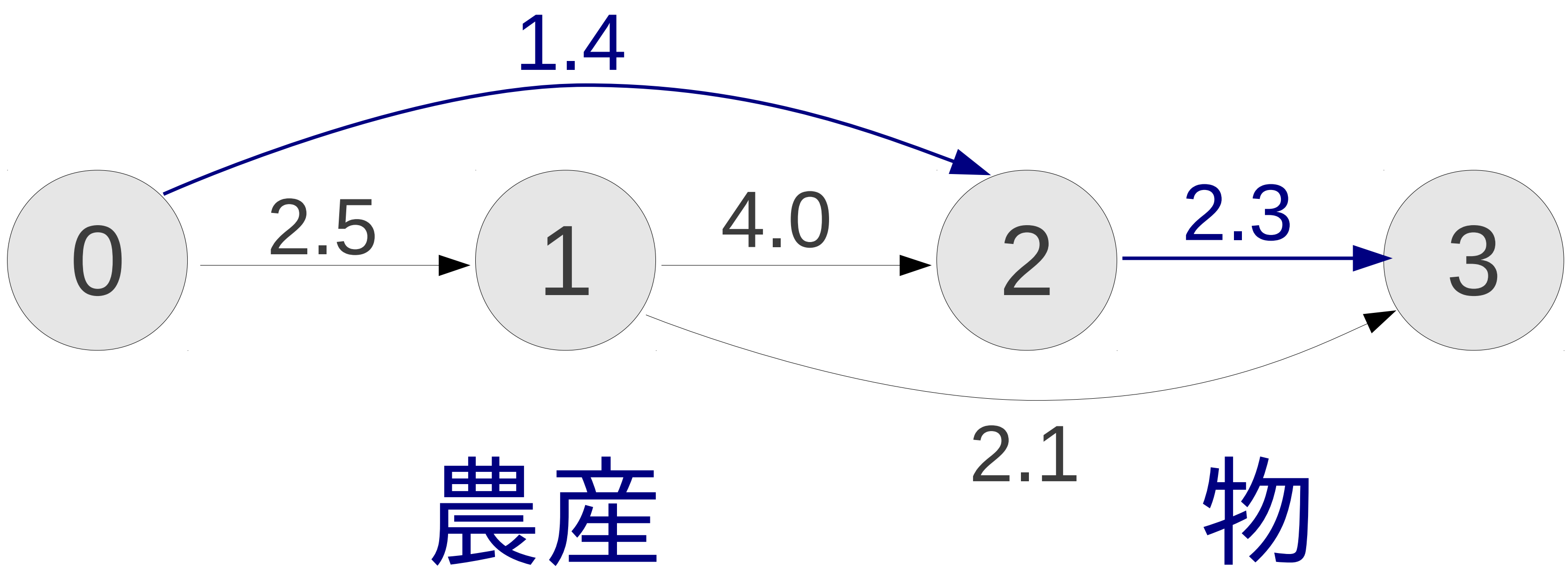
- Why?! (hint, we want the <u>shortest</u> path)

Word Segmentations as Graphs



- Each path is a segmentation for the sentence

Word Segmentations as Graphs



- Each path is a segmentation for the sentence
- Each path weight is a sentence unigram negative log probability

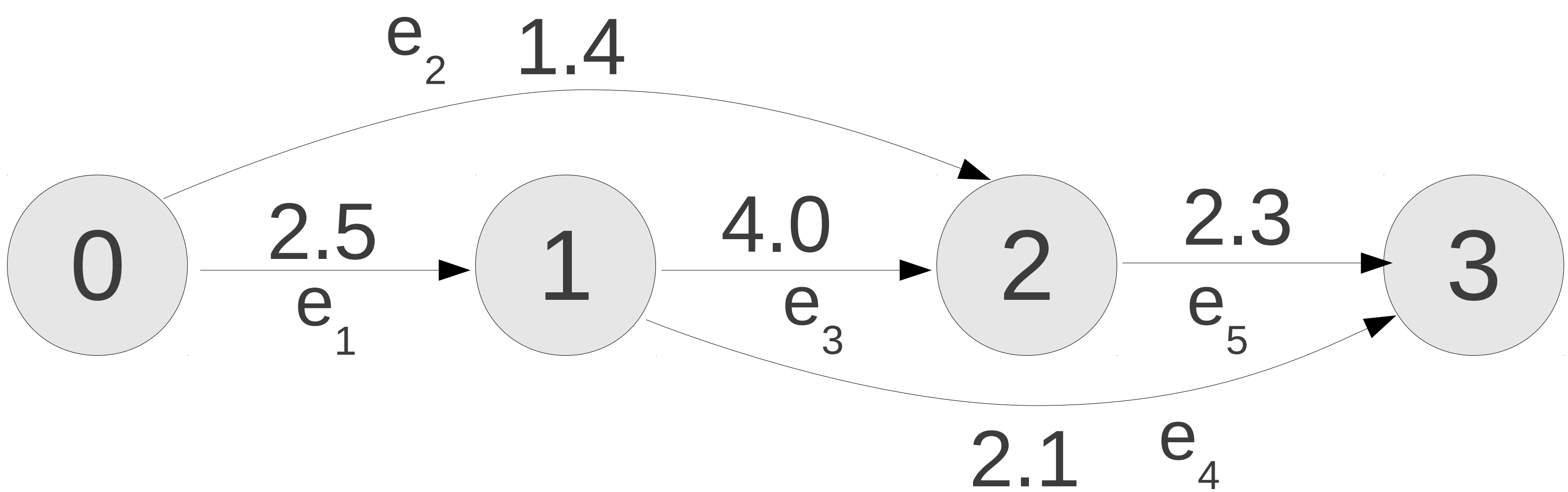
- log(P(農産)) + - log(P(物)) = 1.4 + 2.3 = 3.7

Ok Viterbi, Tell Me More!

- The Viterbi Algorithm has two steps
  - In forward order, find the score of the best path to each node
  - In backward order, create the best path

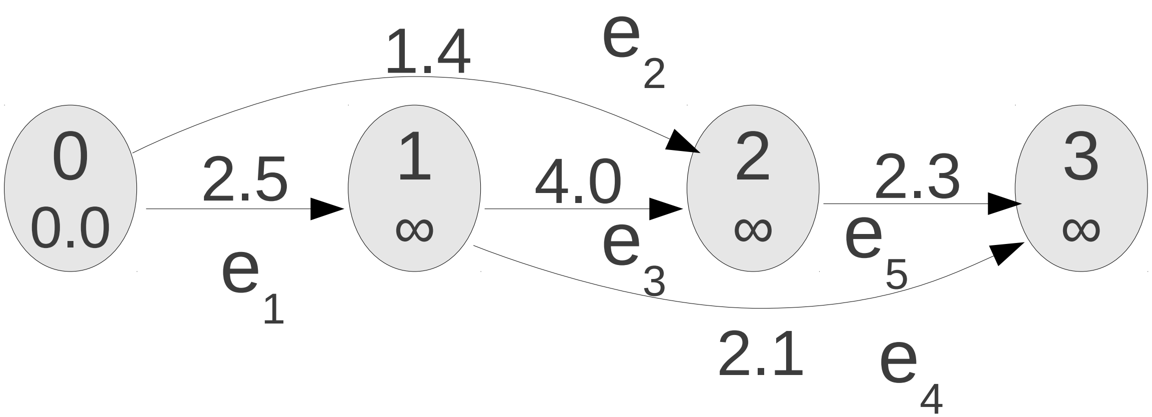
Forward Step

Forward Step



best_score[0] = 0
for each *node* in the *graph* (ascending order)
    best_score[*node*] = ∞
    for each incoming *edge* of *node*
        score = *best_score*[*edge.prev_node*] + *edge.score*
        if *score* < *best_score*[*node*]
            best_score[*node*] = *score*
            best_edge[*node*] = *edge*

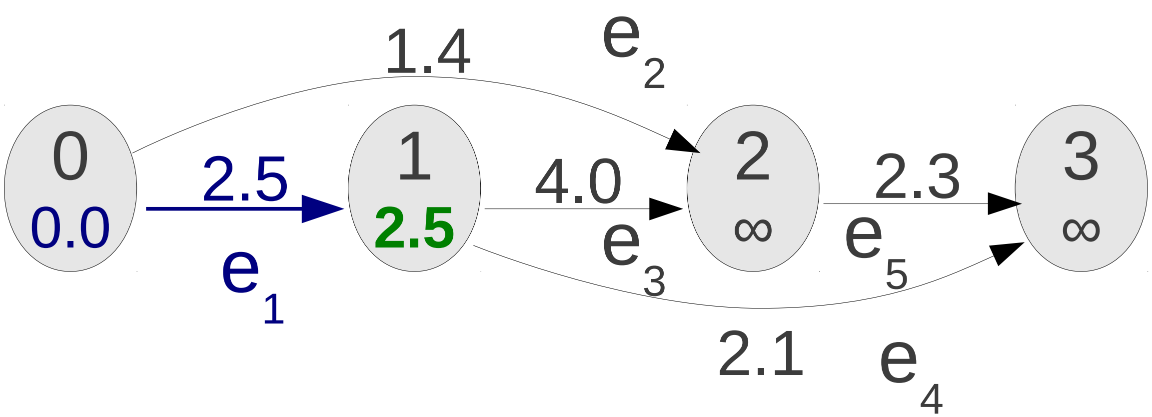
Example:



Initialize:

best_score[0] = 0

Example:



Initialize:

best_score[0] = 0

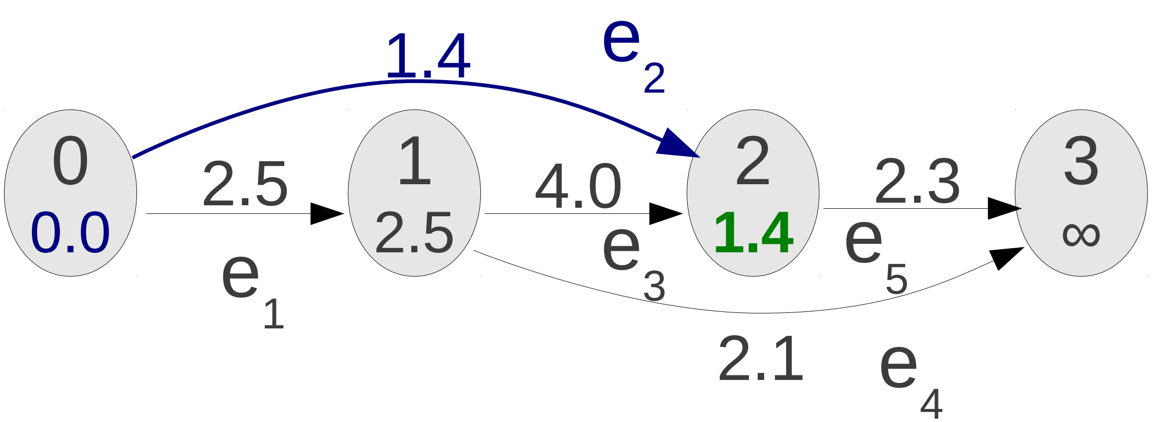
Check e_1:

score = 0 + 2.5 = 2.5 (< ∞)

best_score[1] = 2.5

best_edge[1] = e_1

Example:



Initialize:

best_score[0] = 0

Check e_1:

score = 0 + 2.5 = 2.5 (< ∞)

best_score[1] = 2.5

best_edge[1] = e_1

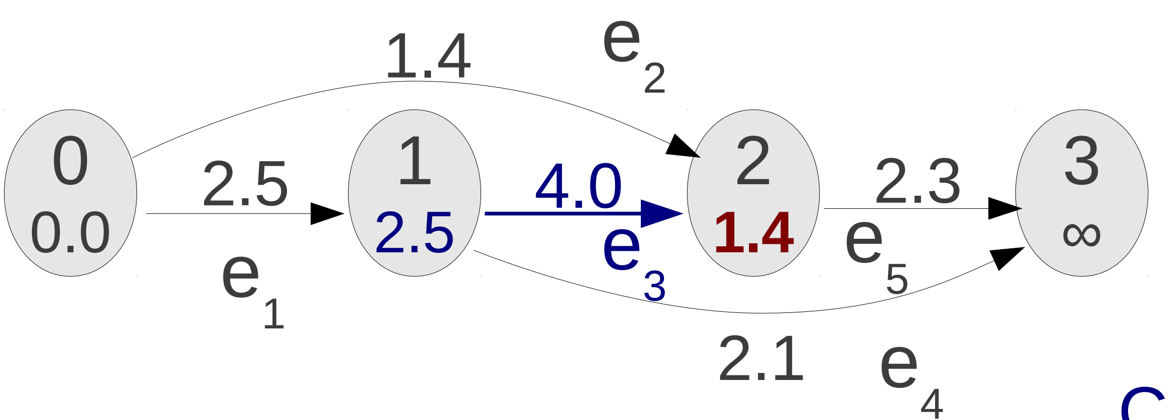
Check e_2:

score = 0 + 1.4 = 1.4 (< ∞)

best_score[2] = 1.4

best_edge[2] = e_2

Example:



Initialize:

best_score[0] = 0

Check e_1:

score = 0 + 2.5 = 2.5 (< ∞)

best_score[1] = 2.5

best_edge[1] = e_1

Check e_2:

score = 0 + 1.4 = 1.4 (< ∞)

best_score[2] = 1.4

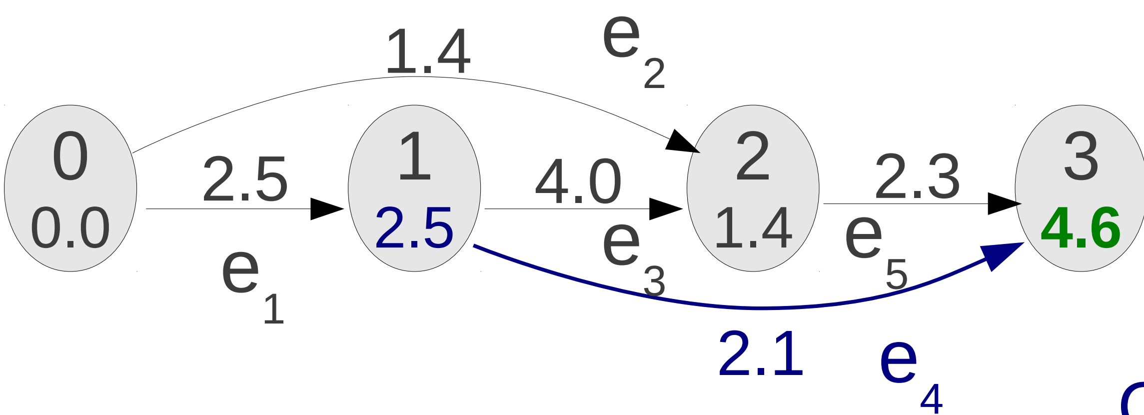
best_edge[2] = e_2

Check e_3:

score = 2.5 + 4.0 = 6.5 (> 1.4)

No change!

Example:



Initialize:

best_score[0] = 0

Check e_1:

score = 0 + 2.5 = 2.5 (< ∞)

best_score[1] = 2.5

best_edge[1] = e_1

Check e_2:

score = 0 + 1.4 = 1.4 (< ∞)

best_score[2] = 1.4

best_edge[2] = e_2

Check e_3:

score = 2.5 + 4.0 = 6.5 (> 1.4)

No change!

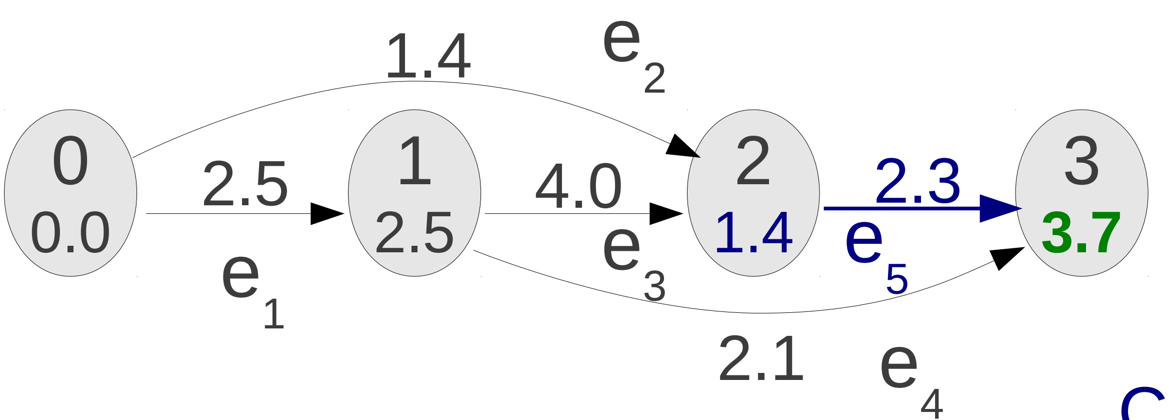
Check e_4:

score = 2.5 + 2.1 = 4.6 (< ∞)

best_score[3] = 4.6

best_edge[3] = e_4

Example:



Initialize:

best_score[0] = 0

Check e_1:

score = 0 + 2.5 = 2.5 (< ∞)

best_score[1] = 2.5

best_edge[1] = e_1

Check e_2:

score = 0 + 1.4 = 1.4 (< ∞)

best_score[2] = 1.4

best_edge[2] = e_2

Check e_3:

score = 2.5 + 4.0 = 6.5 (> 1.4)

No change!

Check e_4:

score = 2.5 + 2.1 = 4.6 (< ∞)

~~best_score[3] = 4.6~~

~~best_edge[3] = e_4~~

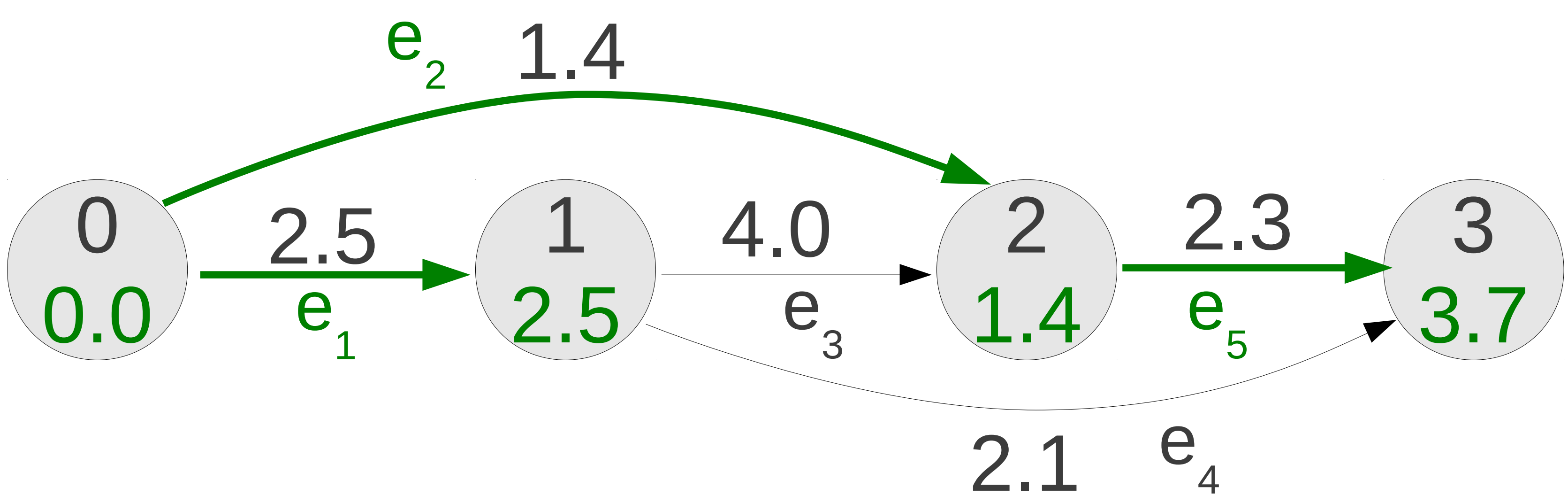
Check e_5:

score = 1.4 + 2.3 = 3.7 (< 4.6)

best_score[3] = 3.7

best_edge[3] = e_5

Result of Forward Step

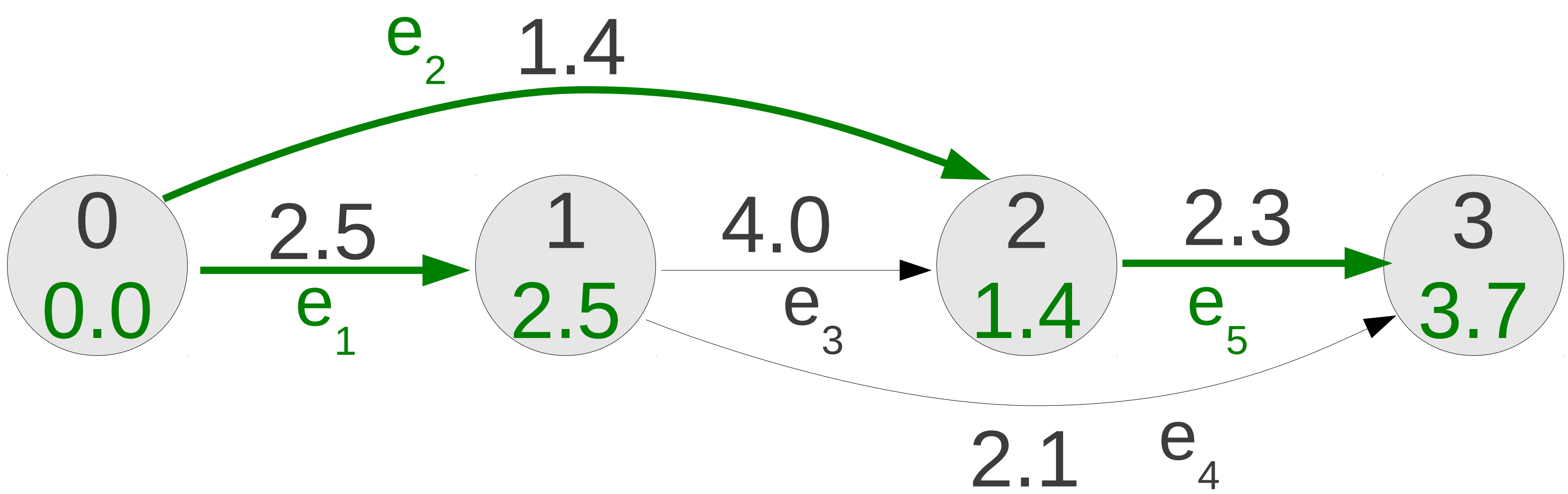


best_score = (0.0, 2.5, 1.4, 3.7)

best_edge = (NULL, e_1, e_2, e_5)

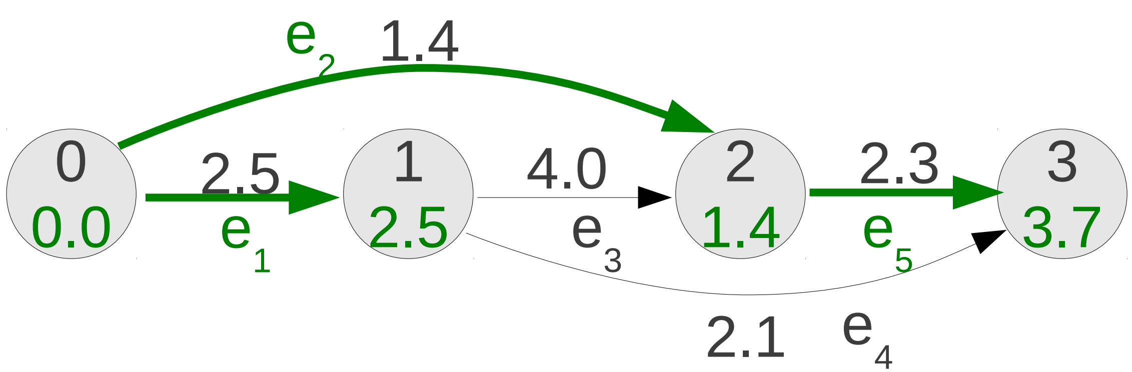
Backward Step

Backward Step



best_path = [ ]
next_edge = *best_edge*[*best_edge*.length – 1]
while *next_edge* != NULL
    add *next_edge* to *best_path*
    next_edge = *best_edge*[*next_edge.prev_node*]
reverse best_path

Example of Backward Step

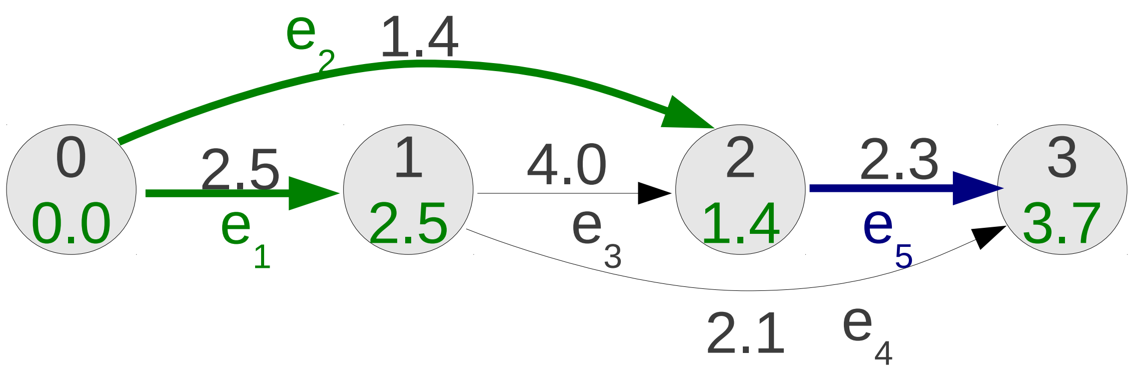


Initialize:

best_path = []

next_edge = best_edge[3] = e_5

Example of Backward Step



Initialize:

best_path = []

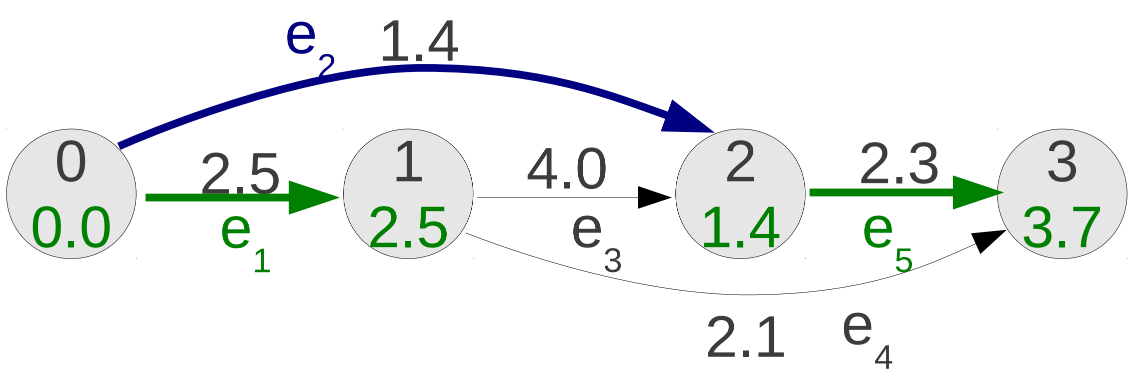
next_edge = best_edge[3] = e_5

Process e_5:

best_path = [e_5]

next_edge = best_edge[2] = e_2

Example of Backward Step



Initialize:

best_path = []
next_edge = best_edge[3] = e_5

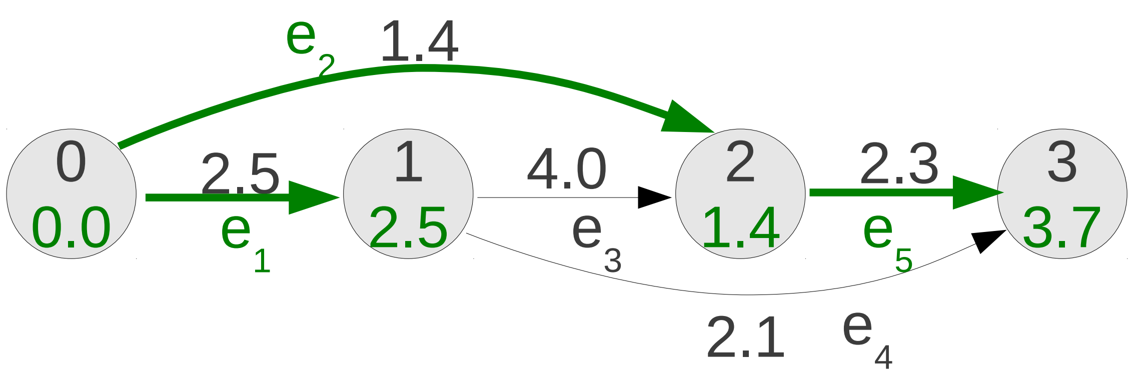
Process e_5:

best_path = [e_5]
next_edge = best_edge[2] = e_2

Process e_2:

best_path = [e_5, e_2]
next_edge = best_edge[0] = NULL

Example of Backward Step



Initialize:

best_path = []
next_edge = best_edge[3] = e_5

Process e_5:

best_path = [e_5]
next_edge = best_edge[2] = e_2

Process e_5:

best_path = [e_5, e_2]
next_edge = best_edge[0] = NULL

Reverse:

best_path = [e_2, e_5]

Tools Required: Reverse

- We must reverse the order of the edges

```
my_list = [ 1, 2, 3, 4, 5 ]
my_list.reverse()

print my_list
```

```
$ ./my-program.py
[5, 4, 3, 2, 1]
```

Word Segmentation with the Viterbi Algorithm

Forward Step for Unigram Word Segmentation

農 産 物

0 1 2 3

0.0 + -log(P(農))

0.0 + -log(P(農産))

best(1) + -log(P(産))

0.0 + -log(P(農産物))

best(1) + -log(P(産物))

best(2) + -log(P(物))

Note: Unknown Word Model

- Remember our probabilities from the unigram model

$$P(w_i)=\lambda_1 P_{ML}(w_i)+(1-\lambda_1)\frac{1}{N}$$

- Model gives equal probability to all unknown words
  P_{unk}(“ｐｒｏｏｆ”) = 1/N
  P_{unk}(“校正（こうせい、英：ｐｒｏｏｆ”) = 1/N
- This is bad for word segmentation
- Solutions:
  - Make better unknown word model (hard but better)
  - Only allow unknown words of length 1 (easy)

Word Segmentation Algorithm (1)

```
load a map of unigram probabilities  # From exercise 1, unigram LM

for each line in the input
    # Forward step
    remove newline and convert line with "unicode()"
    best_edge[0] = NULL
    best_score[0] = 0
    for each word_end in [1, 2, …, length(line)]
        best_score[word_end] = 10^10          # Set to a very large value
        for each word_begin in [0, 1, …, word_end – 1]
            word = line[word_begin:word_end] # Get the substring
            if word is in unigram or length(word) = 1 # Only known words
                prob = P_uni(word)                    # Same as exercise 1
                my_score = best_score[word_begin] + -log( prob )
                if my_score < best_score[word_end]
                    best_score[word_end] = my_score
                    best_edge[word_end] = (word_begin, word_end)
```

Word Segmentation Algorithm (2)

```
# Backward step
words = [ ]
next_edge = best_edge[ length(best_edge) – 1 ]
while next_edge != NULL
    # Add the substring for this edge to the words
    word = line[next_edge[0]:next_edge[1] ]
    encode word with the “encode()” function
    append word to words
    next_edge = best_edge[ next_edge[0] ]
words.reverse()
join words into a string and print
```

Exercise

Exercise

- Write a word segmentation program
- Test the program
  - Model: `test/04-unigram.txt`
  - Input: `test/04-input.txt`
  - Answer: `test/04-answer.txt`
- Train a unigram model on `data/wiki-ja-train.word` and run the program on `data/wiki-ja-test.txt`
- Measure the accuracy of your segmentation with
  `script/gradews.pl data/wiki-ja-test.word my_answer.word`
- Report the column F-meas

Challenges

- Use data/big-ws-model.txt and measure the accuracy
- Improve the unknown word model
- Use a bigram model

Thank You!