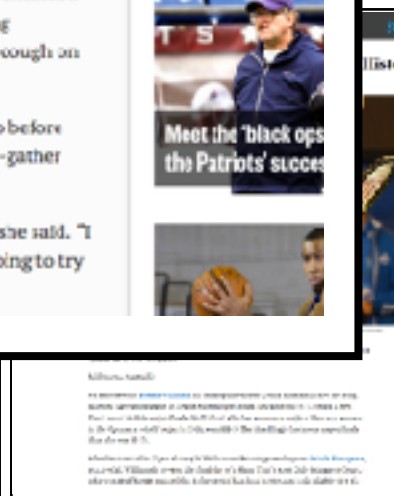
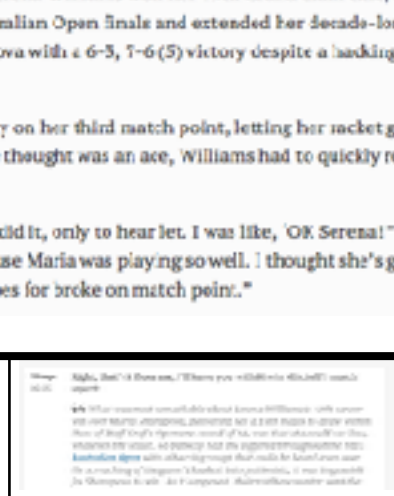
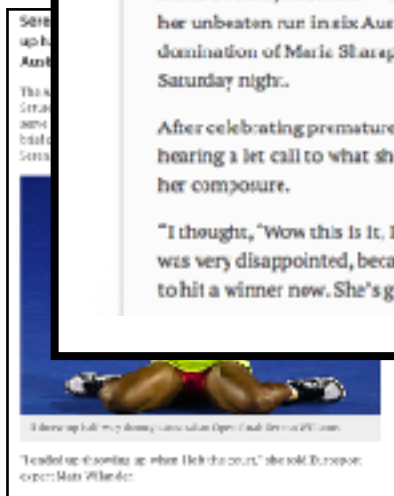
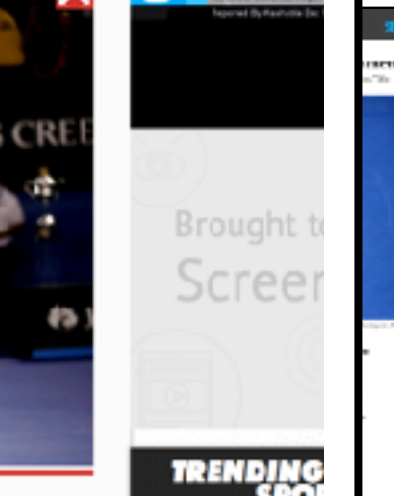
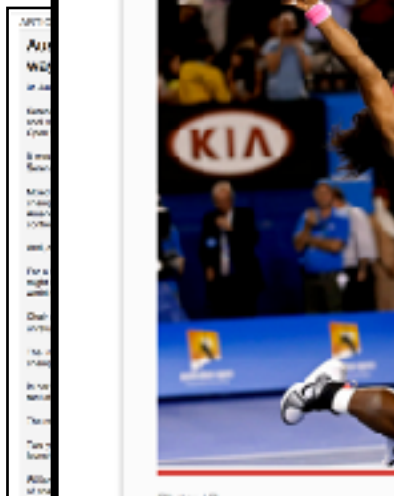
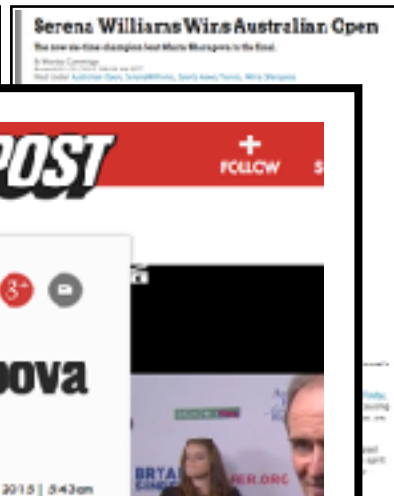
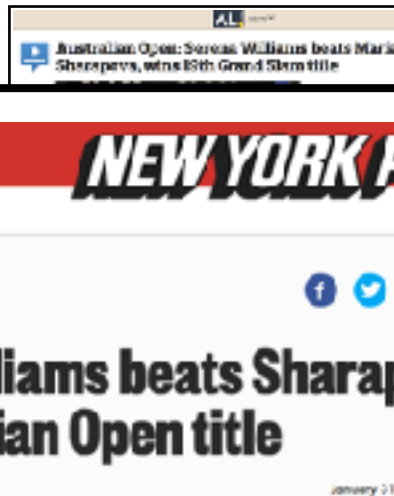
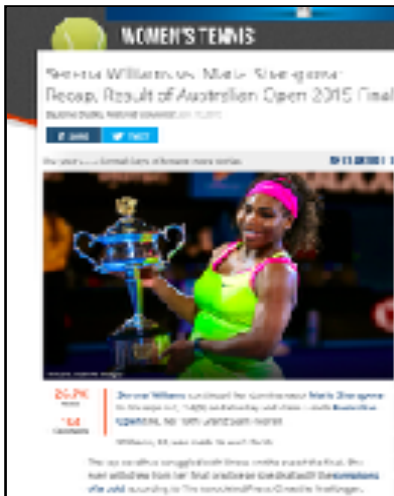


# Multi-Document Summarization

# Multi-Document Summarization

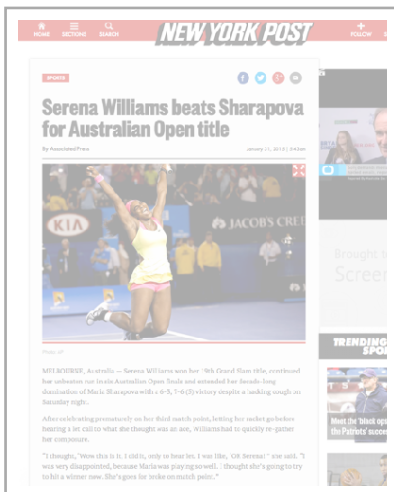








# Multi-Document Summarization

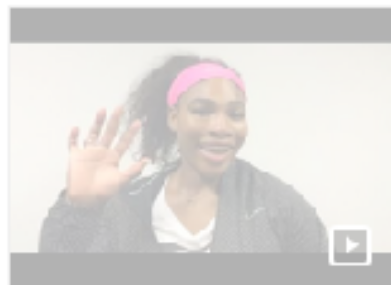


# Google News

## Serena beats Sharapova for 19th Grand Slam

The Star Democrat - 30 minutes ago

Serena Williams celebrates after defeating Maria Sharapova in the women's singles final Saturday at the Australian Open. Williams beats Sharapova again, wins 19th Grand Slam title. AP PHOTO ...



WTA



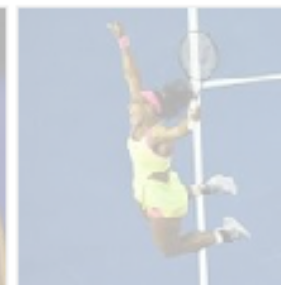
YouTube



YouTube



Eurosport.com ASIA



New York Times



Miami Herald.com



New York Daily News

### Serena Williams wins 6th Australian, 19th major title

Colorado Springs Gazette - 7 minutes ago

### Serena Williams Wins 6th Australian Open Title

Latin American Herald Tribune - 16 minutes ago

### TENNIS: Serena Williams wins 6th Australian Open, 19th major title

The Times Herald - 1 hour ago

### Serena overpowers Sharapova to win 19th Grand Slam title

Daily Times - 1 hour ago

### Serena Williams wins Australian Open to capture 19th Grand Slam title

National Post - 3 hours ago

[See all 4,853 articles »](#)



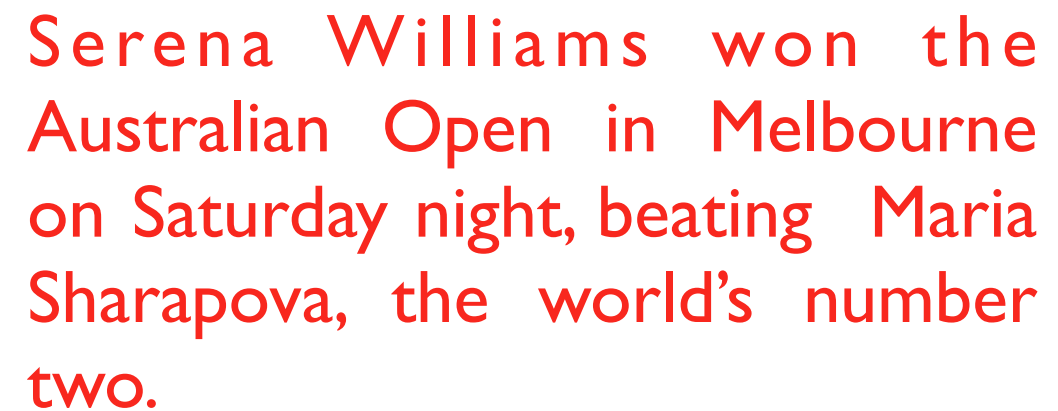
# Abstractive Summarization

Serena Williams, while suffering from a severe cold, won her 19th Grand Slam title by beating Maria Sharapova in the Australian Open. This victory puts her a step closer to the world record for total number of Grand Slam wins.

# Extractive Summarization



Length  
 $\leq K$   
words



Length  
 $\leq K$   
words



# Extractive Summarization



Serena Williams won the Australian Open in Melbourne on Saturday night, beating Maria Sharapova, the world's number two. This victory represents Williams' 19th Grand Slam singles title as she moves closer to Steffi Graf's record of 22 titles in the Open era.

Length  
 $\leq K$   
words

# Extractive Summarization



Serena Williams won the Australian Open in Melbourne on Saturday night, beating Maria Sharapova, the world's number two. This victory represents Williams' 19th Grand Slam singles title as she moves closer to Steffi Graf's record of 22 titles in the Open era.

Length  
 $\leq K$   
words

# Sentence Compression



Serena Williams won the Australian Open ~~in Melbourne on Saturday night,~~ beating Maria Sharapova, ~~the world's number two.~~ This victory represents Williams' 19th Grand Slam singles title ~~as she moves closer to Steffi Graf's record of 22 titles in the Open era.~~

Length  
 $\leq K$   
words



# Sentence Compression



Serena Williams won the Australian Open ~~in Melbourne on Saturday night,~~ beating Maria Sharapova, ~~the world's number two.~~ This victory represents Williams' 19th Grand Slam singles title ~~as she moves closer to Steffi Graf's record of 22 titles in the Open era.~~ Williams was reportedly suffering from a severe cold throughout the tournament, but she didn't let that distract her.

Length  
 $\leq K$   
words

# Sentence Compression



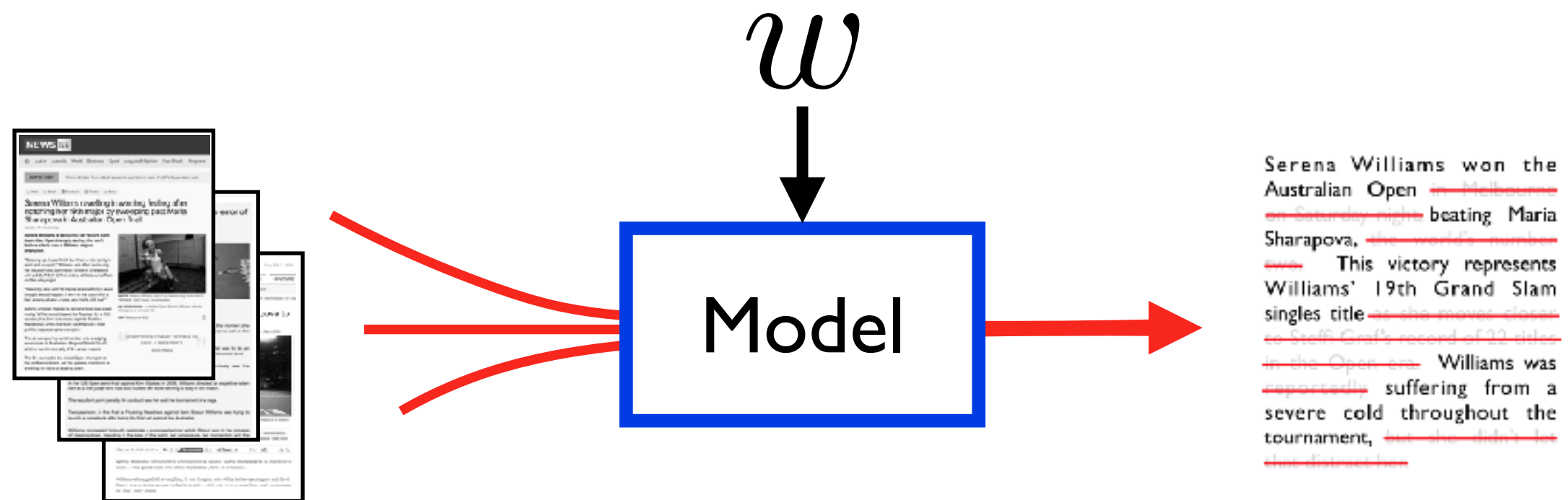
Serena Williams won the Australian Open ~~in Melbourne on Saturday night,~~ beating Maria Sharapova, ~~the world's number two.~~ This victory represents Williams' 19th Grand Slam singles title ~~as she moves closer to Steffi Graf's record of 22 titles in the Open era.~~ Williams was ~~reportedly~~ suffering from a severe cold throughout the tournament, ~~but she didn't let that distract her.~~

Length  
 $\leq K$   
words

# Learning to Summarize



# Finding the Best Summary



# Finding the Best Summary

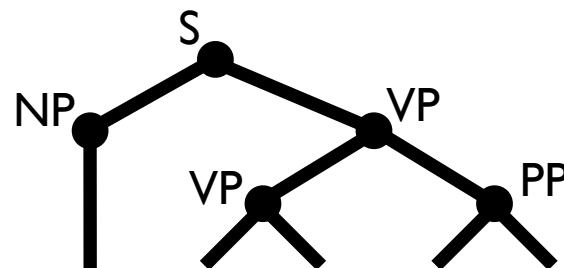
$\mathcal{W}$



Coverage

Australian open  
nineteenth major  
court year  
career  
beat Sharapova  
first match  
Saturday  
set  
second  
first  
Maria  
held  
19th title  
tennis  
point  
Melbourne Australia  
points  
serve victory  
Williams won  
Grand Slam  
more  
time

Coherence

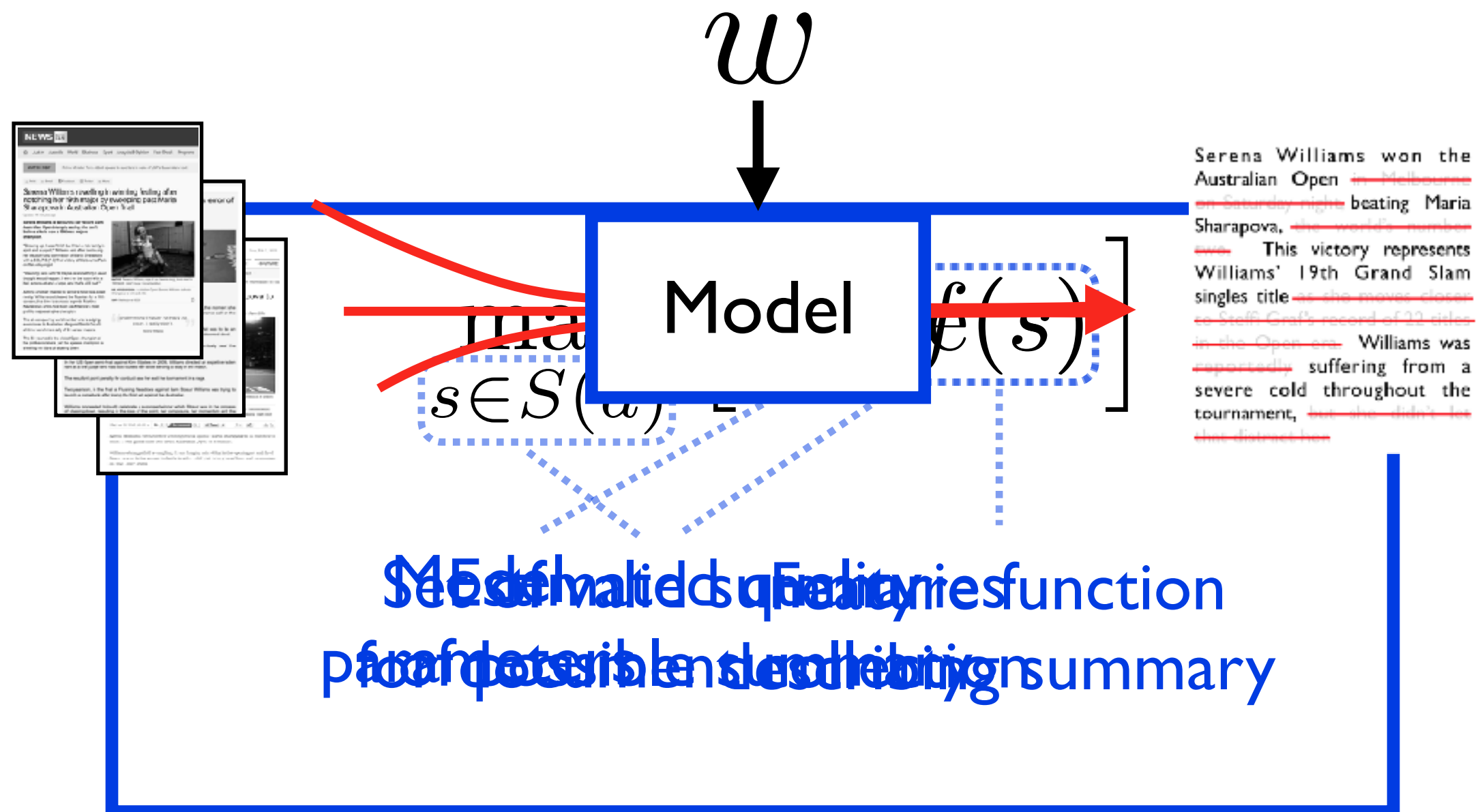


Serena Williams won the Australian Open in Melbourne on Saturday night beating Maria Sharapova, the world number one. This victory represents Williams' 19th Grand Slam singles title as the power player to Staff Gra's record of 22 titles in the Open era. Williams was reportedly suffering from a severe cold throughout the tournament, but she didn't let it affect her.

# Finding the Best Summary

Document  
collection:  $d$

Summary:  $s$





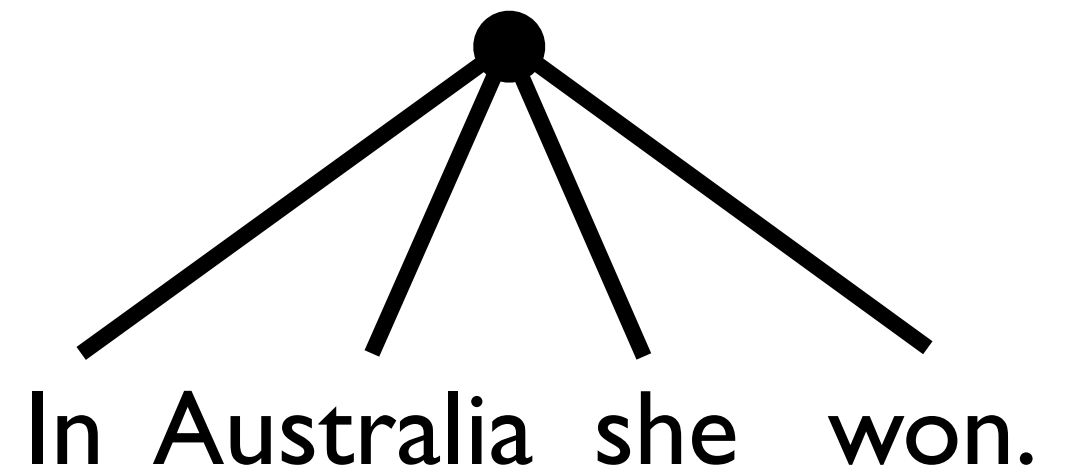
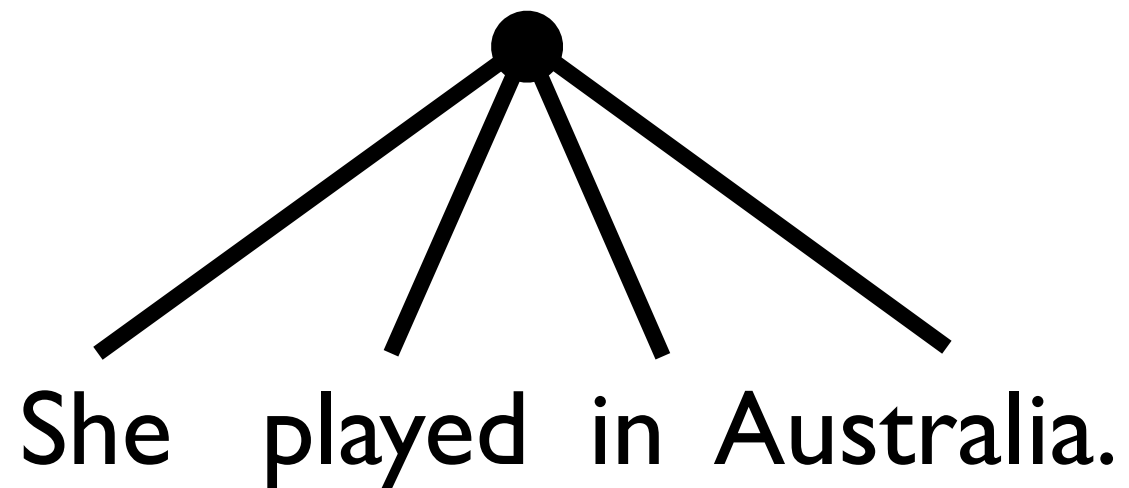
# Extractive Model

---

She played in Australia.

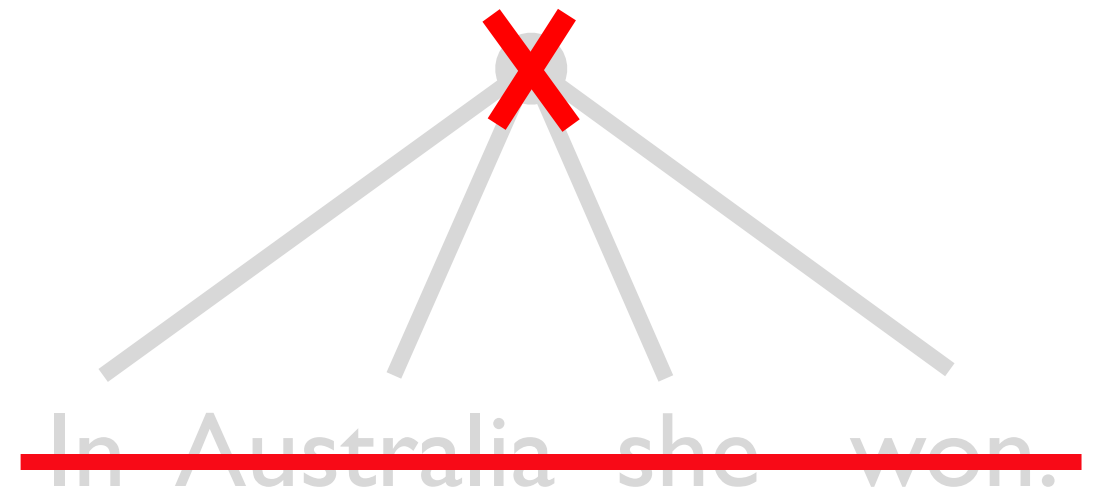
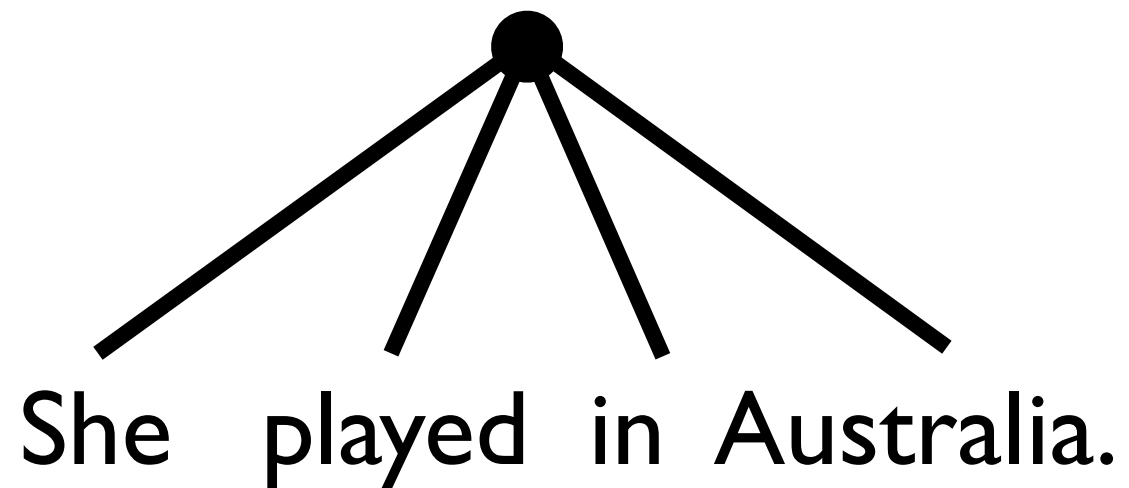
# Extractive Model

---



# Extractive Model

---

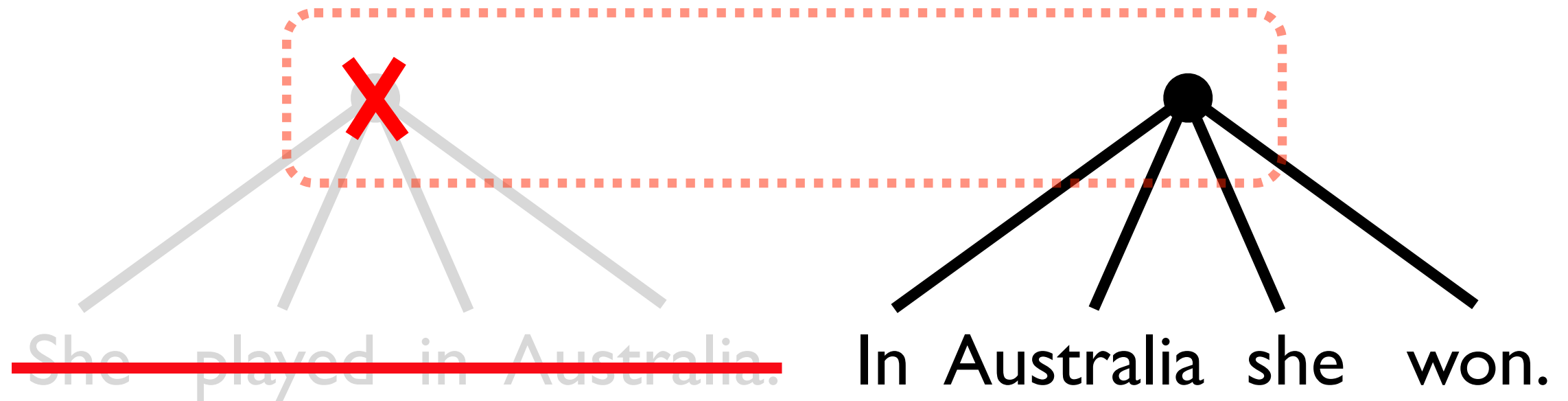




# Extractive Model

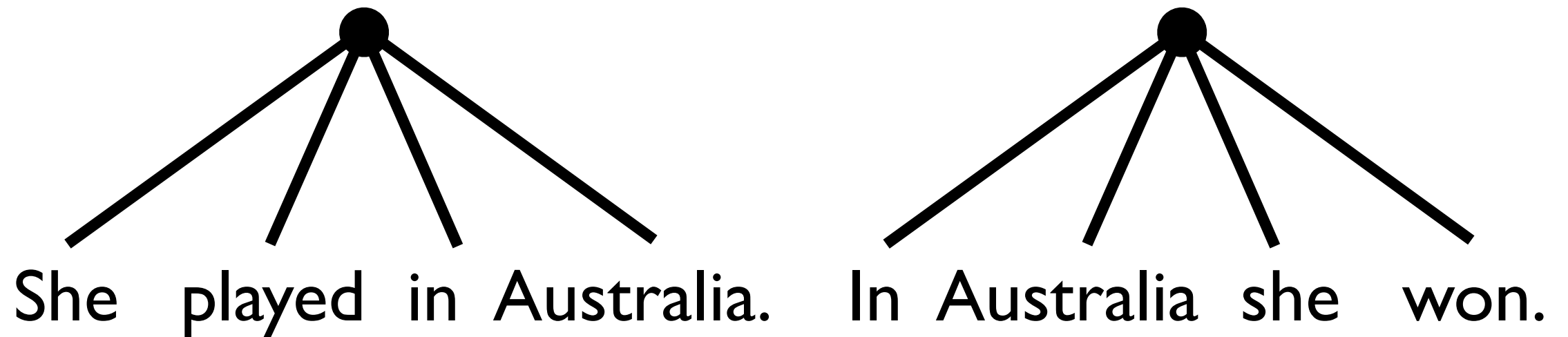
---

A summary is a set of cuts:  $S$



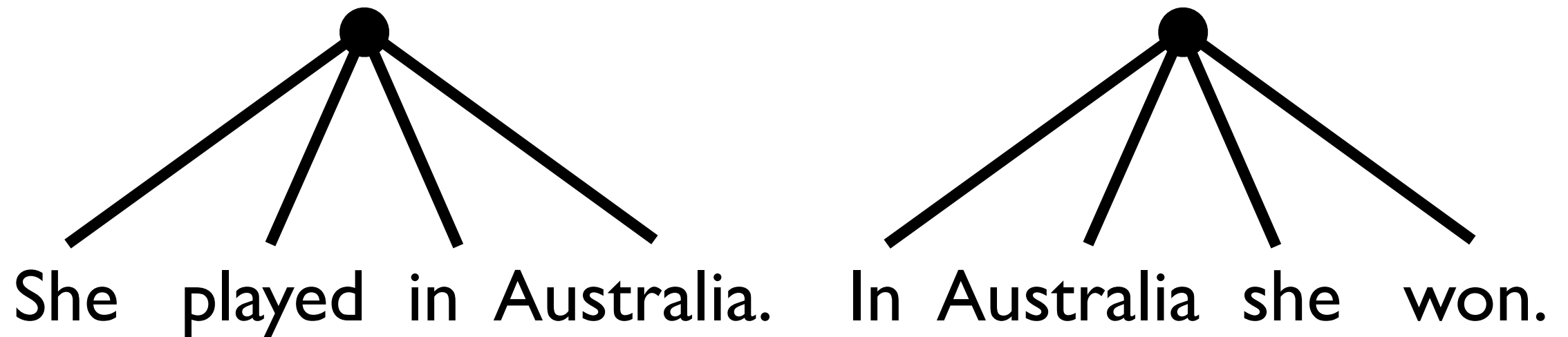
# Extractive Model

---



# Extractive Model

---



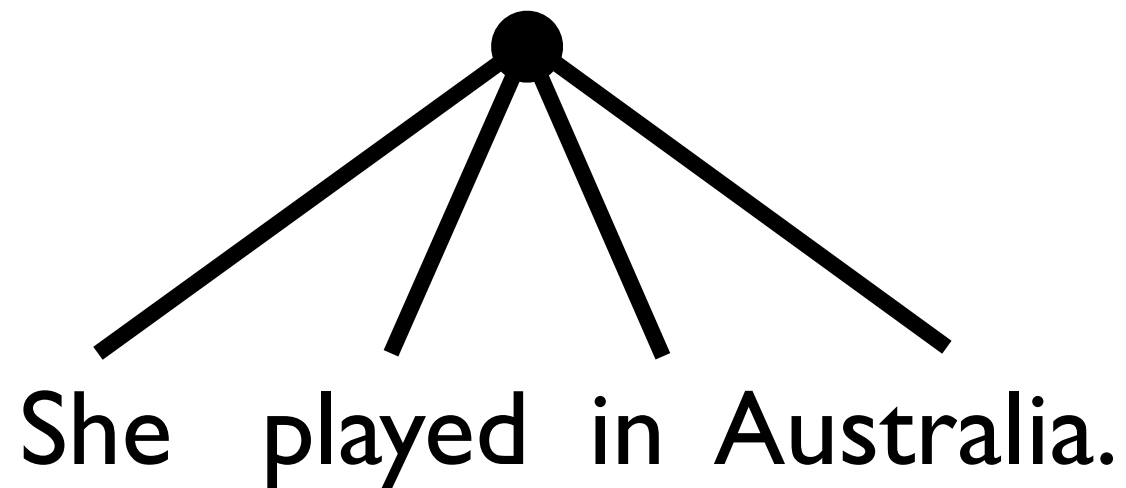
(she, played) ✓  
(played, in) ✓

(in, australia) ✓  
(australia, she) ✓

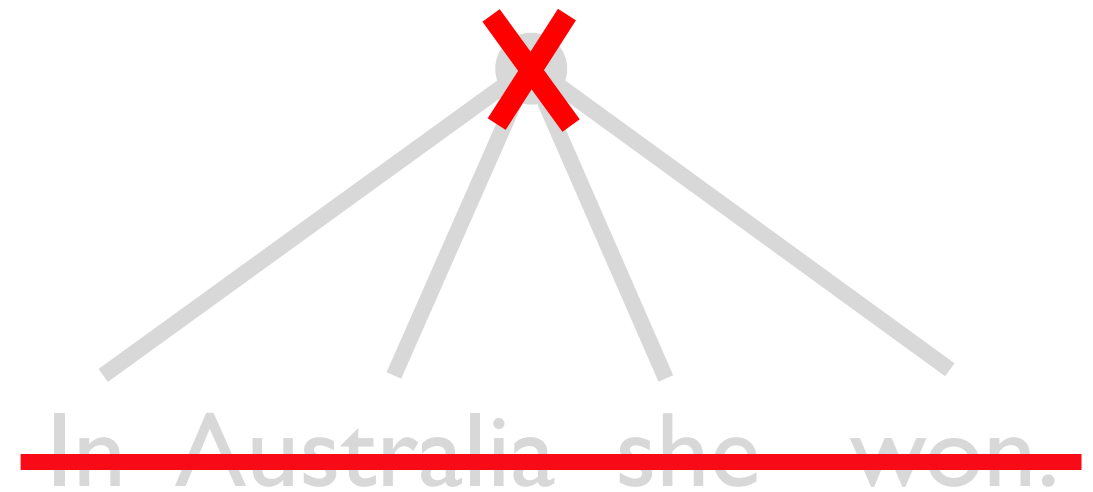
(she, won) ✓

# Extractive Model

---



(she, played) ✓  
(played, in) ✓



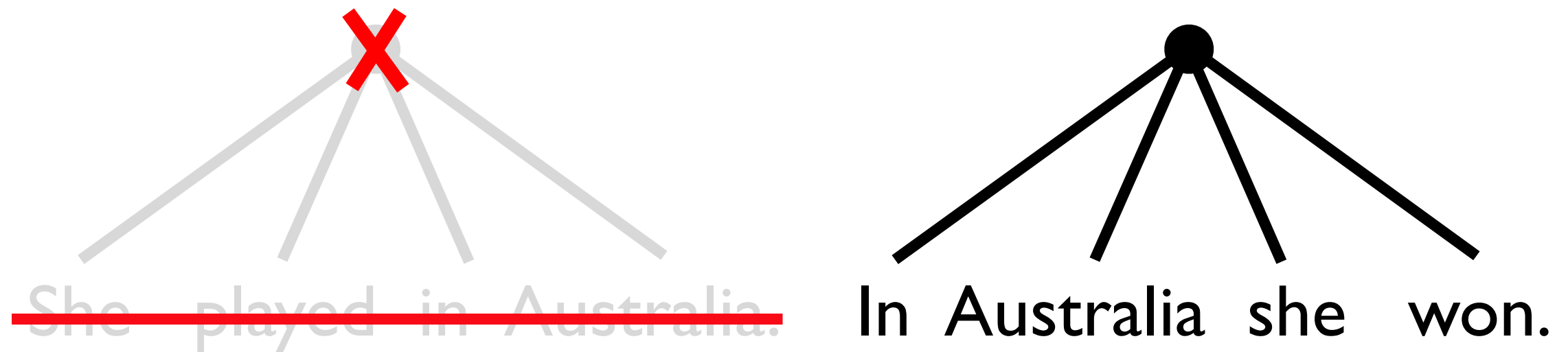
(in, australia) ✓  
(australia, she)

(she, won)



# Extractive Model

---



(she, played)

(played, in)

(in, australia) ✓

(australia, she) ✓

(she, won) ✓

Set of bigrams covered by summary:  $B(s)$

# Search

---

$$\max_s \text{coverage}(s)$$

# Search

---

$$\max_s \sum_{b \in B(s)} \text{value}(b)$$

$$\text{s.t.} \quad \text{length}(s) \leq K$$

$$\text{value}(b) = \text{doc\_count}(b)$$

# Search

---

$$\begin{aligned} \max_s \quad & \sum_{b \in B(s)} \text{value}(b) \\ \text{s.t.} \quad & \text{length}(s) \leq K \end{aligned}$$

Parameterize using features:

$$\text{value}(b) = w^\top f(b)$$

doc count?   position?   part-of-speech?



# Search

---

$$\begin{aligned} \max_s \quad & \sum_{b \in B(s)} \text{value}(b) \\ \text{s.t.} \quad & \text{length}(s) \leq K \end{aligned}$$

Integer Linear Program

# Search

---

$$\max_{s, z} \sum_b z_b \cdot \text{value}(b)$$

$$\text{s.t.} \quad \text{length}(s) \leq K$$

bigrams in  $s$  are covered

only bigrams in  $s$  are covered

Integer Linear Program

# Search

---

$$\max_{s, z} \sum_b z_b \cdot \text{value}(b)$$

$$\text{s.t.} \quad \sum_n l_n s_n \leq K$$

bigrams in  $S$  are covered

only bigrams in  $S$  are covered

Integer Linear Program

# Search

---

$$\begin{aligned} \max_{s, z} \quad & \sum_b z_b \cdot \text{value}(b) \\ \text{s.t.} \quad & \sum_n l_n s_n \leq K \\ & \forall_{n, b} \quad s_n Q_{nb} \leq z_b \\ & \forall_b \quad \sum_n s_n Q_{nb} \geq z_b \end{aligned}$$

Integer Linear Program



**Full Model**

# Extractive / Compressive Model

---

She played in Australia. ~~In Australia~~ she won.

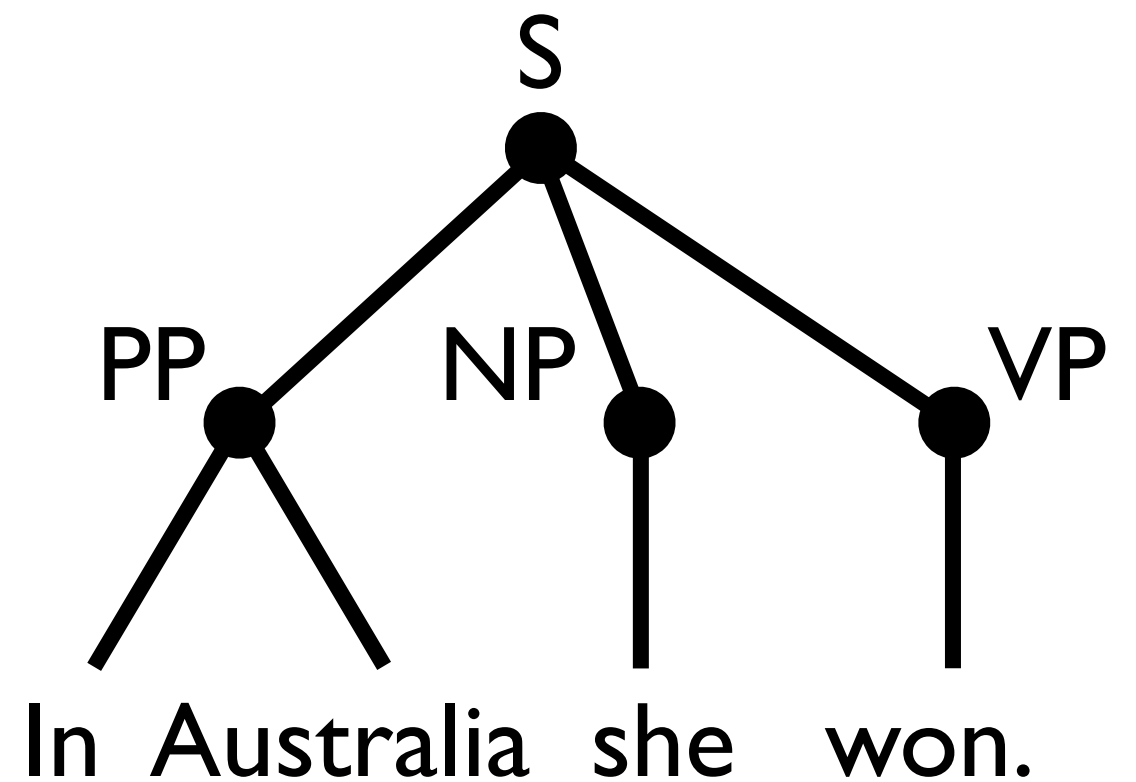
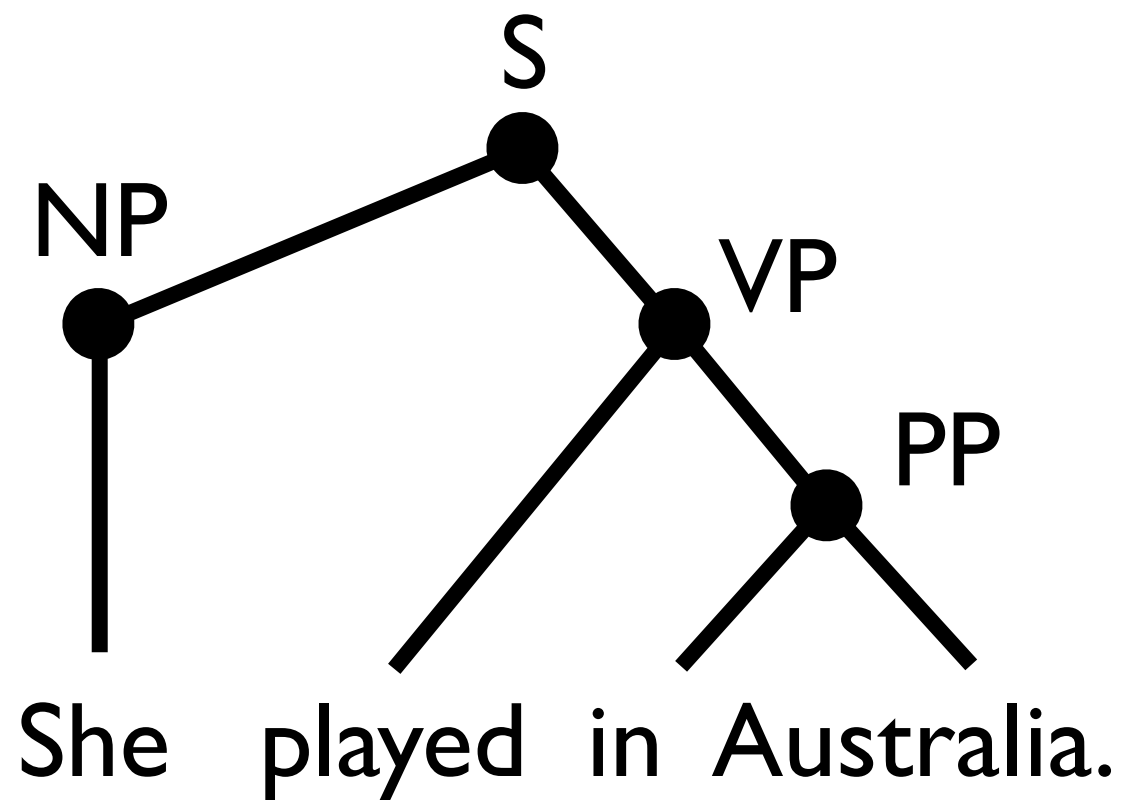
# Extractive / Compressive Model

---



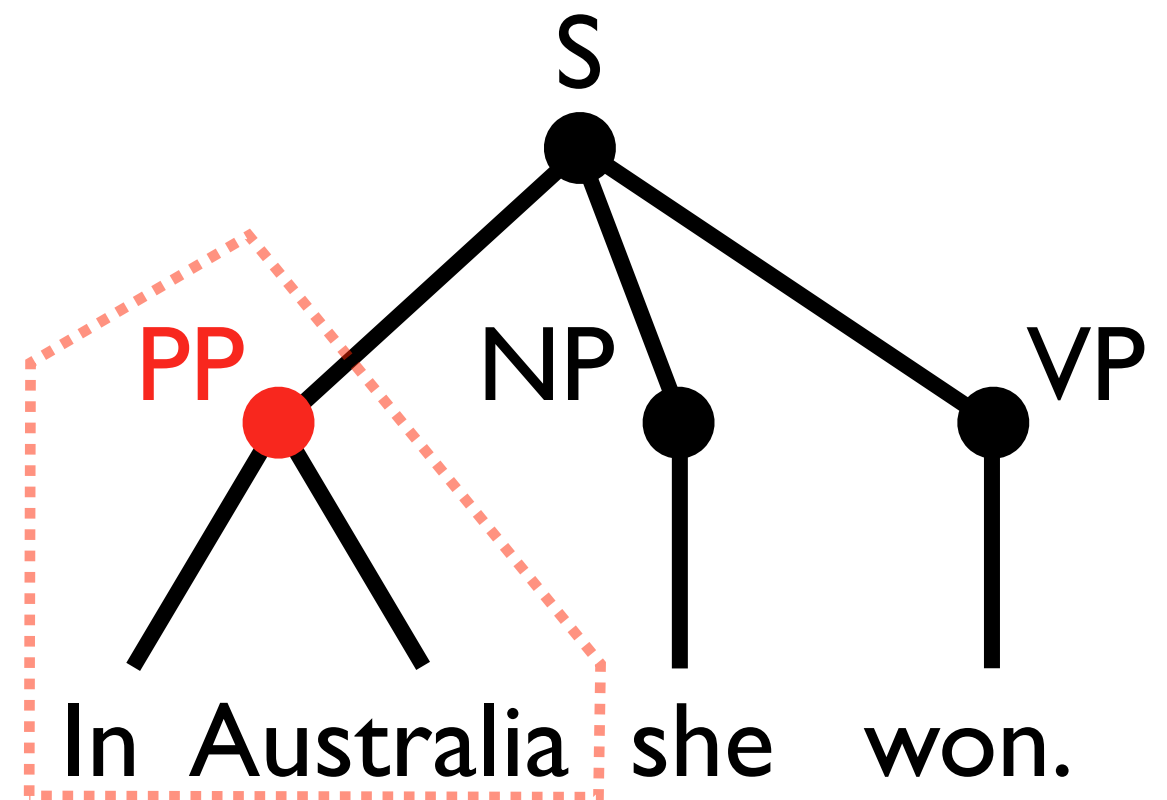
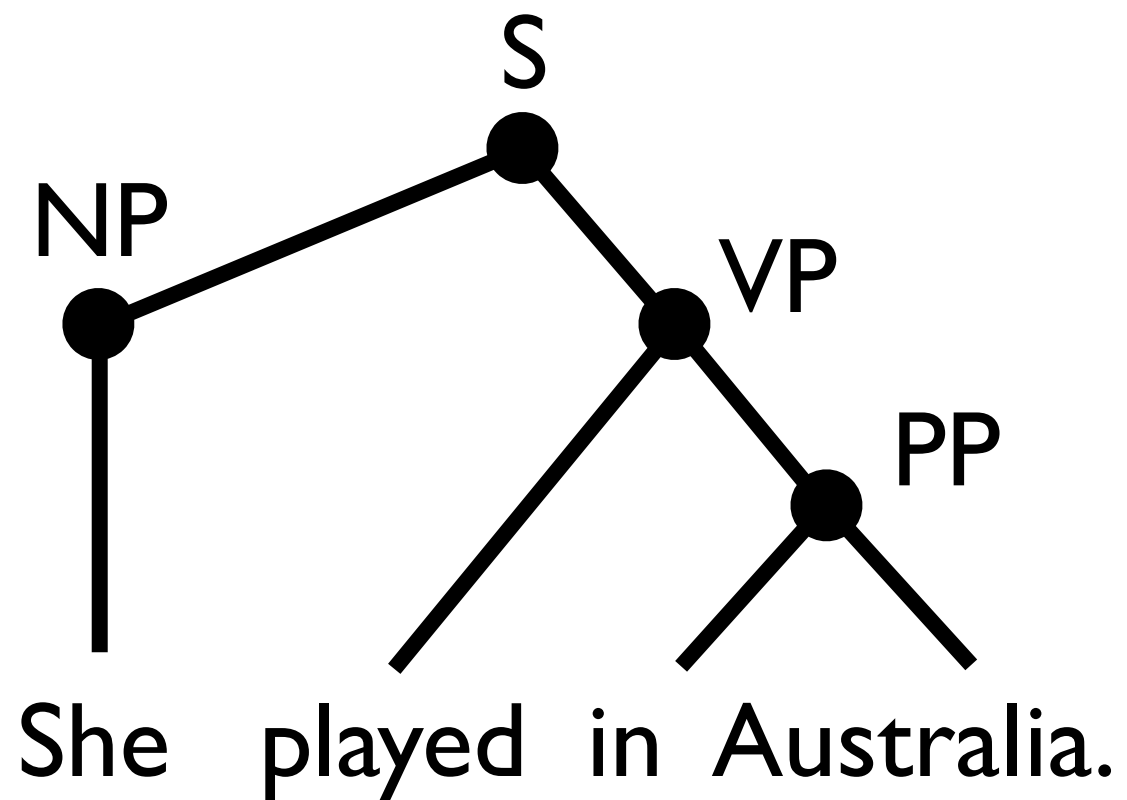
# Extractive / Compressive Model

---



# Extractive / Compressive Model

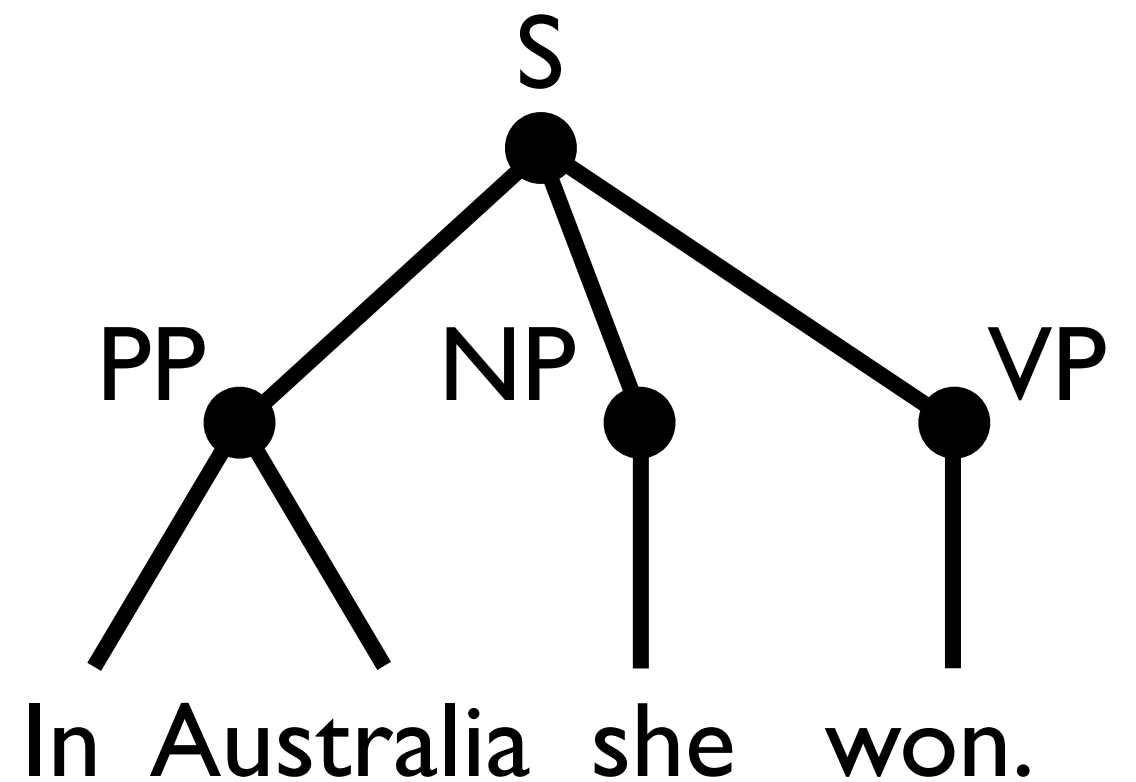
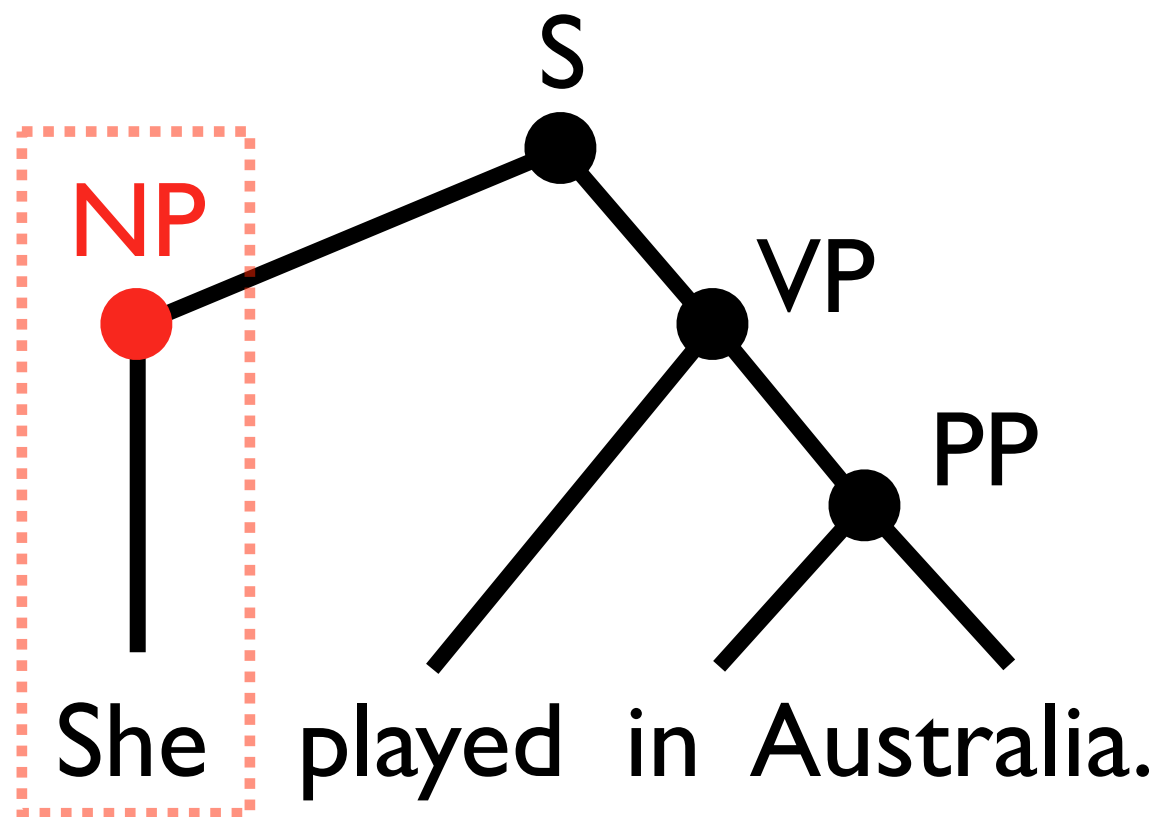
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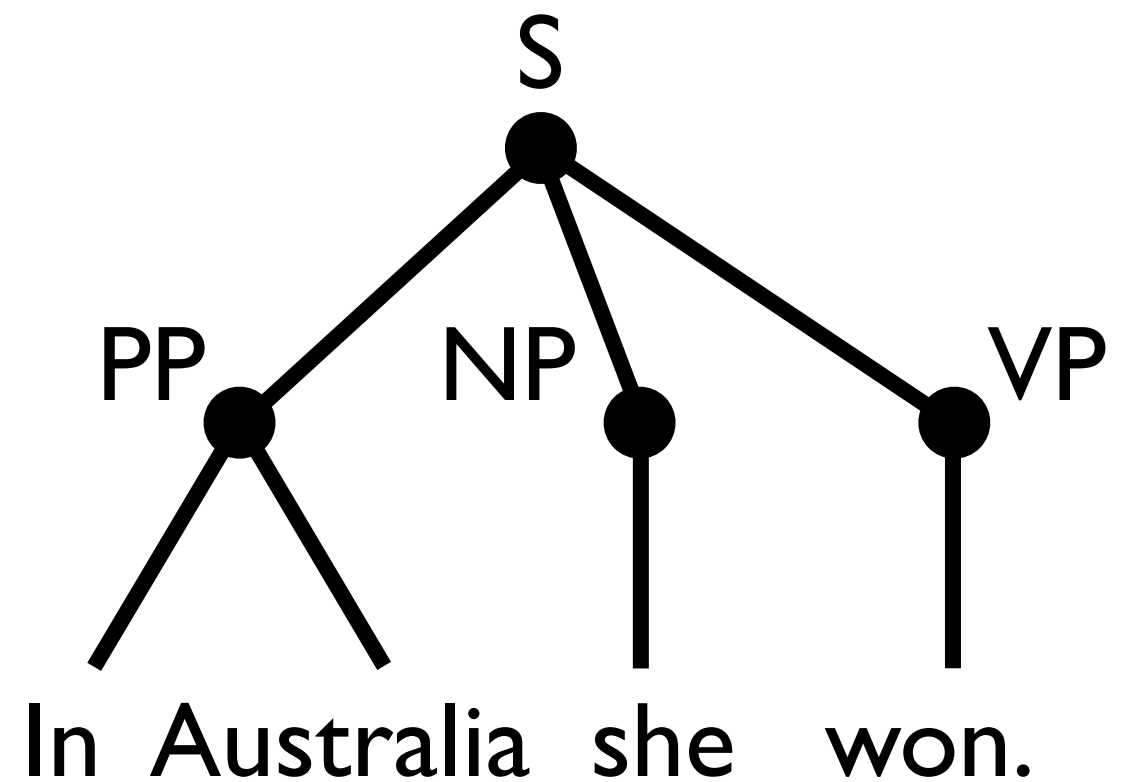
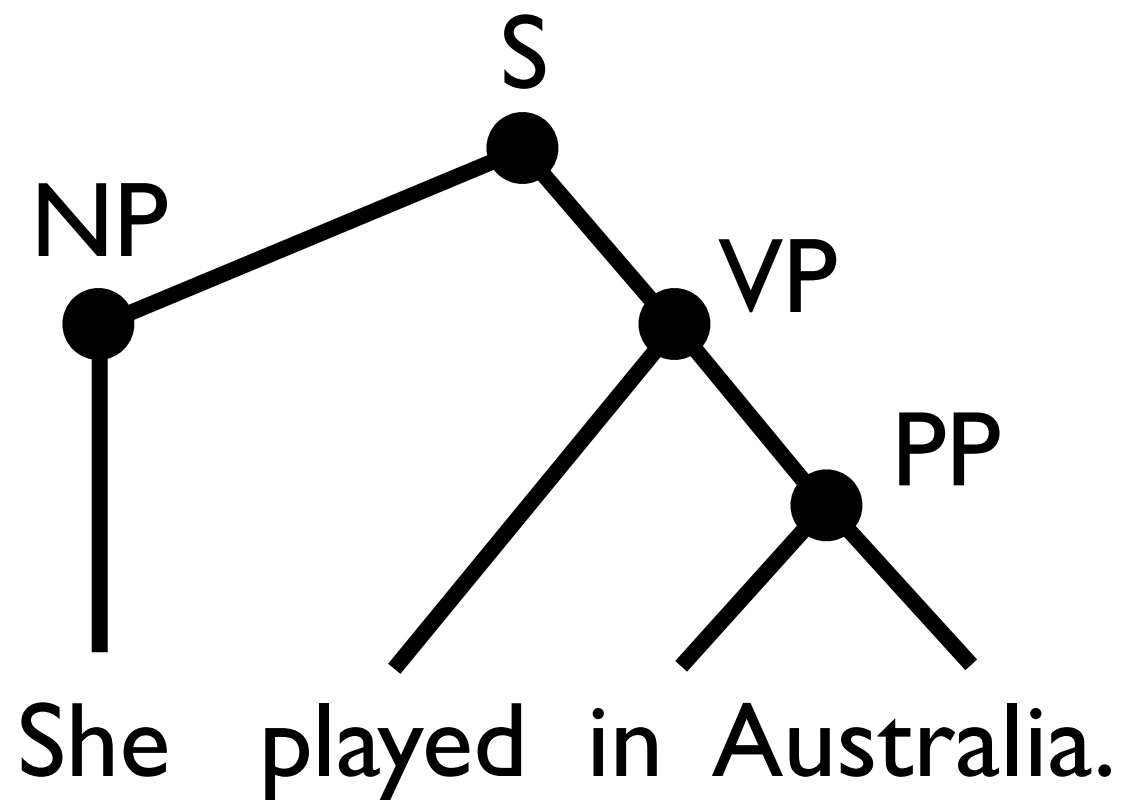
# Extractive / Compressive Model

---



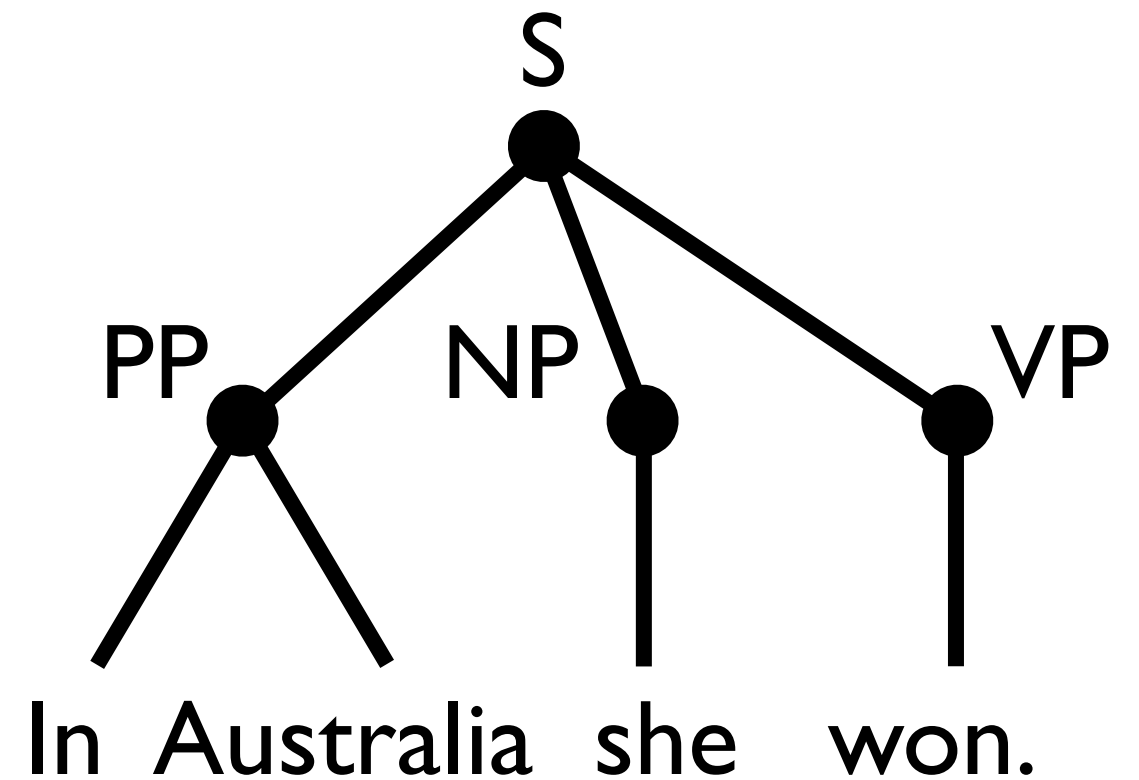
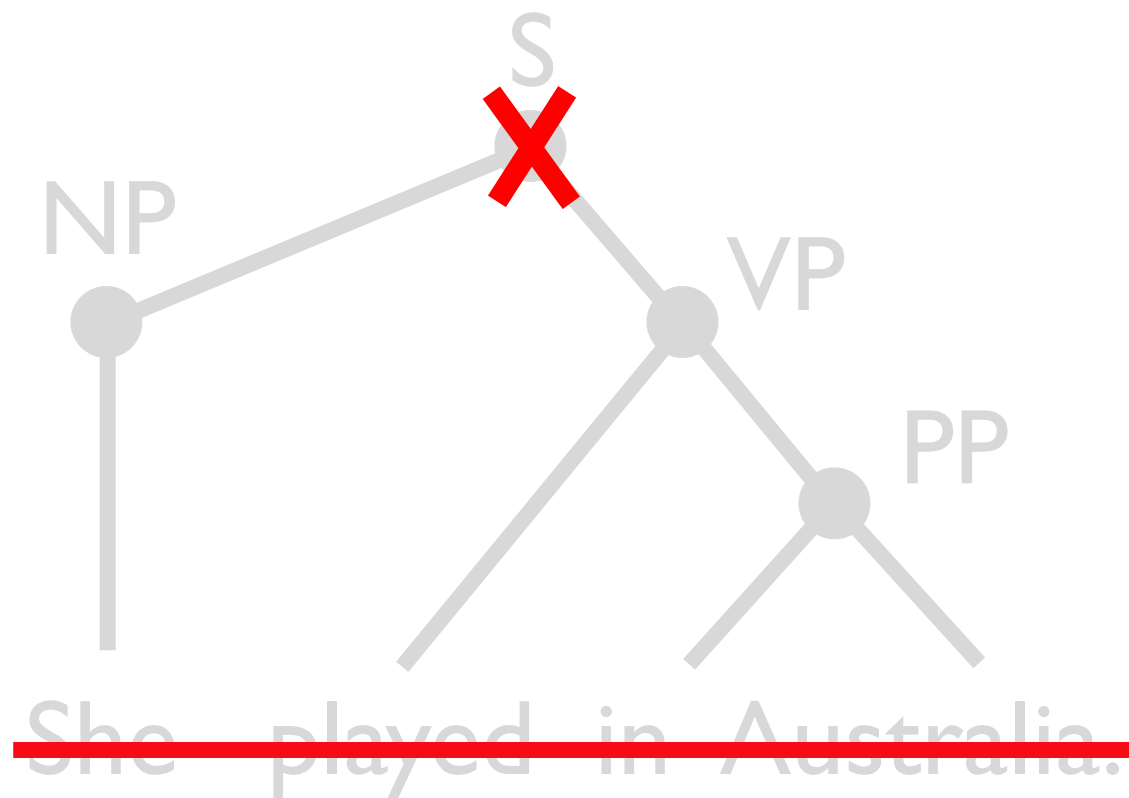
# Extractive / Compressive Model

---



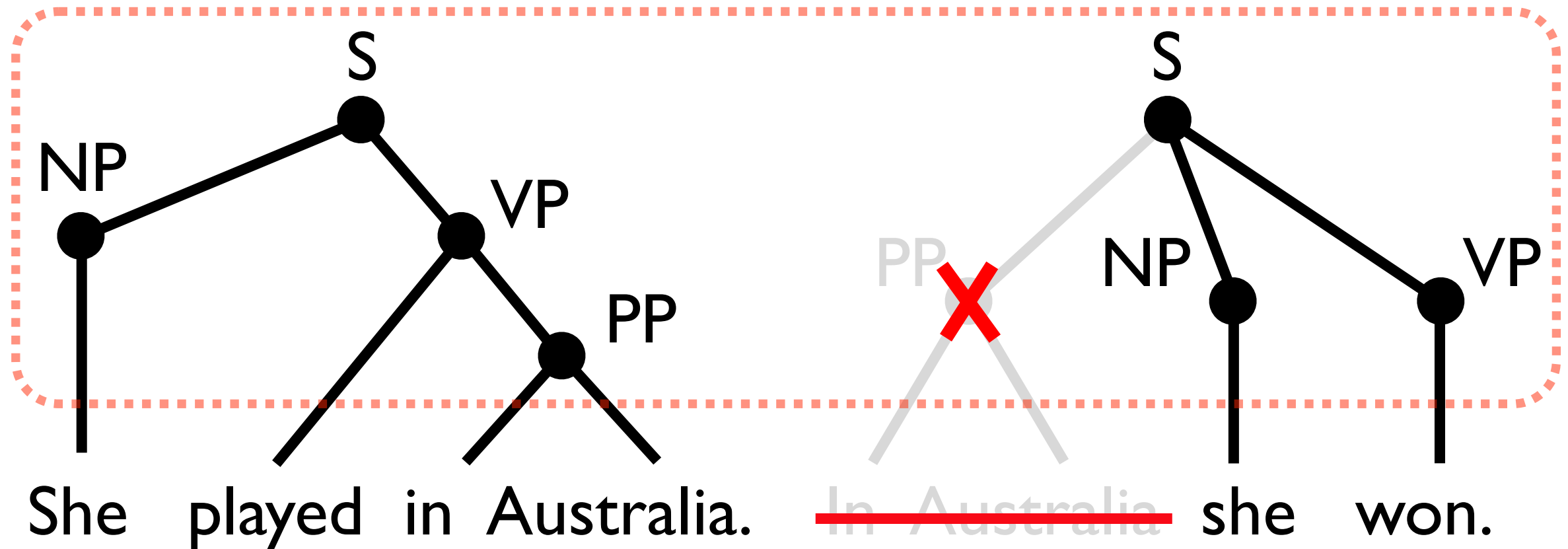
# Extractive / Compressive Model

---



# Extractive / Compressive Model

$s$



(she, played) ✓  
(played, in) ✓

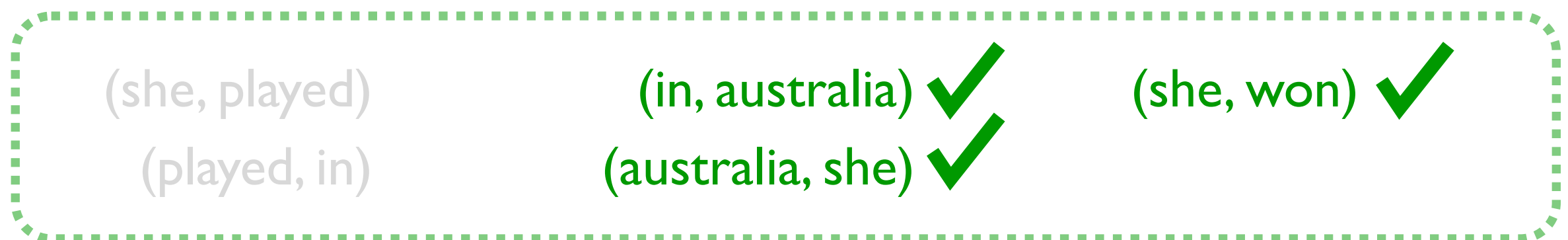
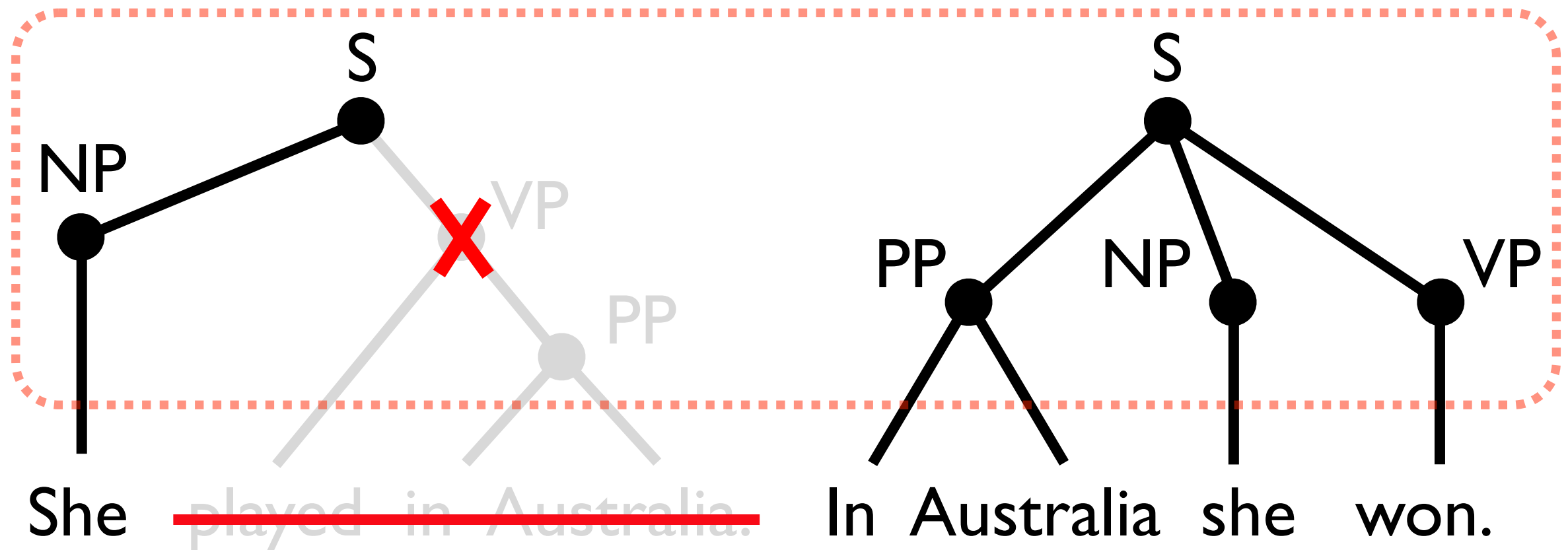
(in, australia) ✓  
(australia, she)

(she, won) ✓

$B(s)$

# Extractive / Compressive Model

$s$



$B(s)$

# Extractive / Compressive Model

---

$$\begin{aligned} & \text{Coverage} && \text{Coherence} \\ \max_s & \left[ \sum_{b \in B(s)} \text{value}(b) + \sum_{c \in s} \text{value}(c) \right] \\ \text{s.t.} & \text{length}(s) \leq K \end{aligned}$$

Parameterize using features:

$$\text{value}(c) = w^\top f(c)$$

label?    parent label?    head word?

# Extractive / Compressive Model

---

$$\max_s \left[ \sum_{b \in B(s)} \text{value}(b) + \sum_{c \in s} \text{value}(c) \right]$$

$$\text{s.t. } \text{length}(s) \leq K$$

Bigram features:

$$\text{value}(b) = w^\top f(b)$$

doc count? position? part-of-speech?

Cut features:

$$\text{value}(c) = w^\top f(c)$$

label? parent label? head word?



# Extractive / Compressive Model

---

$$\max_s \left[ \sum_{b \in B(s)} w^\top f(b) + \sum_{c \in s} w^\top f(c) \right]$$

$$\text{s.t. } \text{length}(s) \leq K$$

Bigram features:

$$\text{value}(b) = w^\top f(b)$$

doc count?   position?   part-of-speech?

Cut features:

$$\text{value}(c) = w^\top f(c)$$

label?   parent label?   head word?

# Extractive / Compressive Model

---

$$\max_s \left[ w^\top \left( \sum_{b \in B(s)} f(b) + \sum_{c \in s} f(c) \right) \right]$$

$$\text{s.t. } \text{length}(s) \leq K$$

Bigram features:

$$\text{value}(b) = w^\top f(b)$$

doc count?   position?   part-of-speech?

Cut features:

$$\text{value}(c) = w^\top f(c)$$

label?   parent label?   head word?

# Extractive / Compressive Model

$$\max_{s \in S(d)} \left[ w^\top f(s) \right]$$

Model parameters:  
describing summary  
Learned from examples of  
collection / summary pairs

Bigram features:

$$\text{value}(b) = w^\top f(b)$$

doc count? position? part-of-speech?

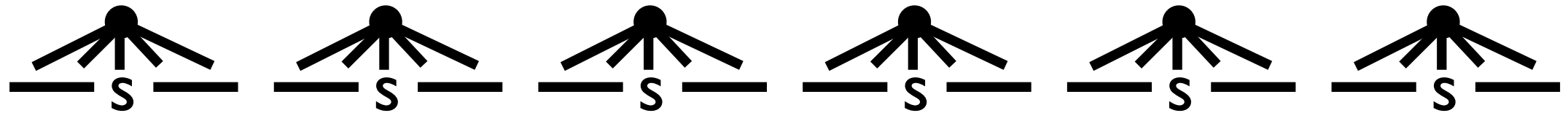
Cut features:

$$\text{value}(c) = w^\top f(c)$$

label? parent label? head word?

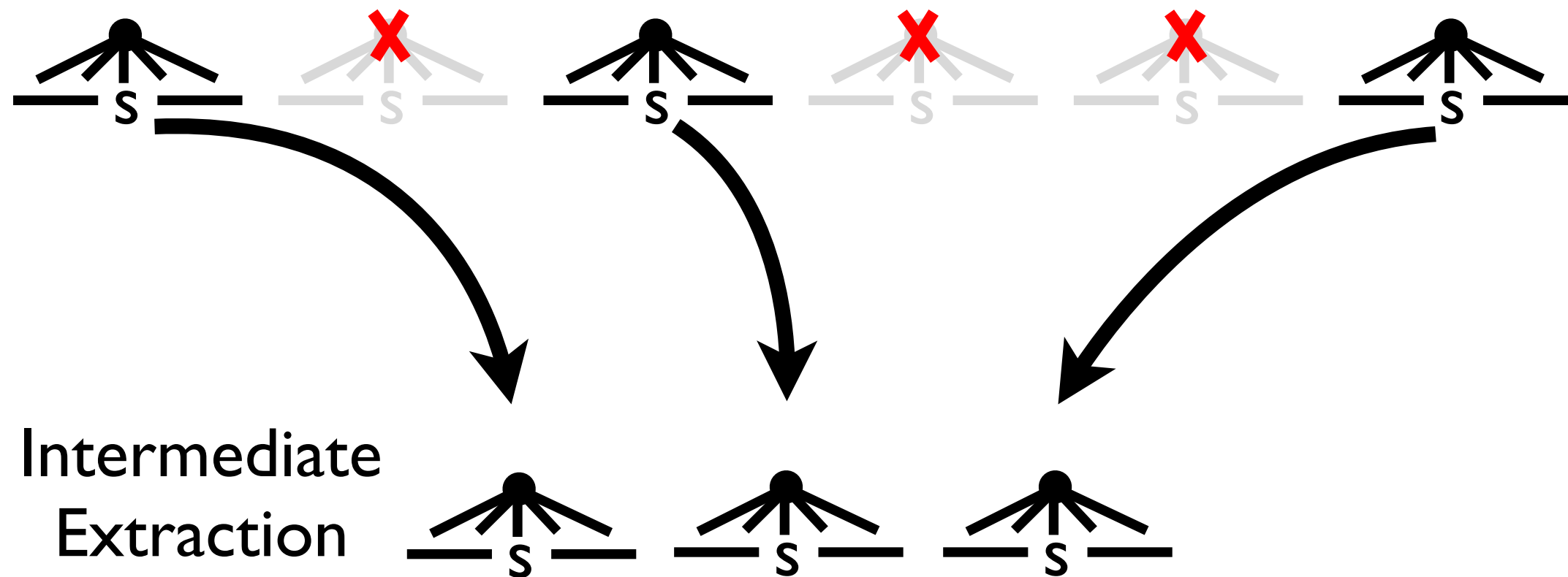
# Coarse-to-fine Inference

---



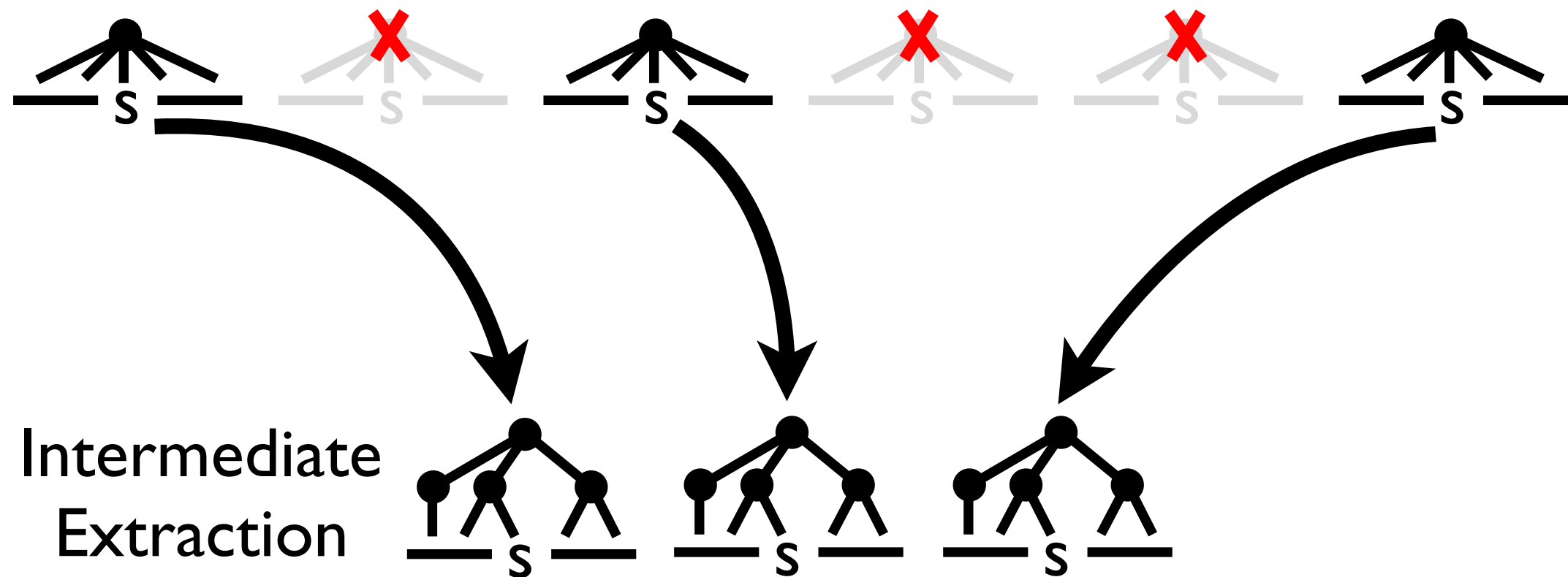
# Coarse-to-fine Inference

---

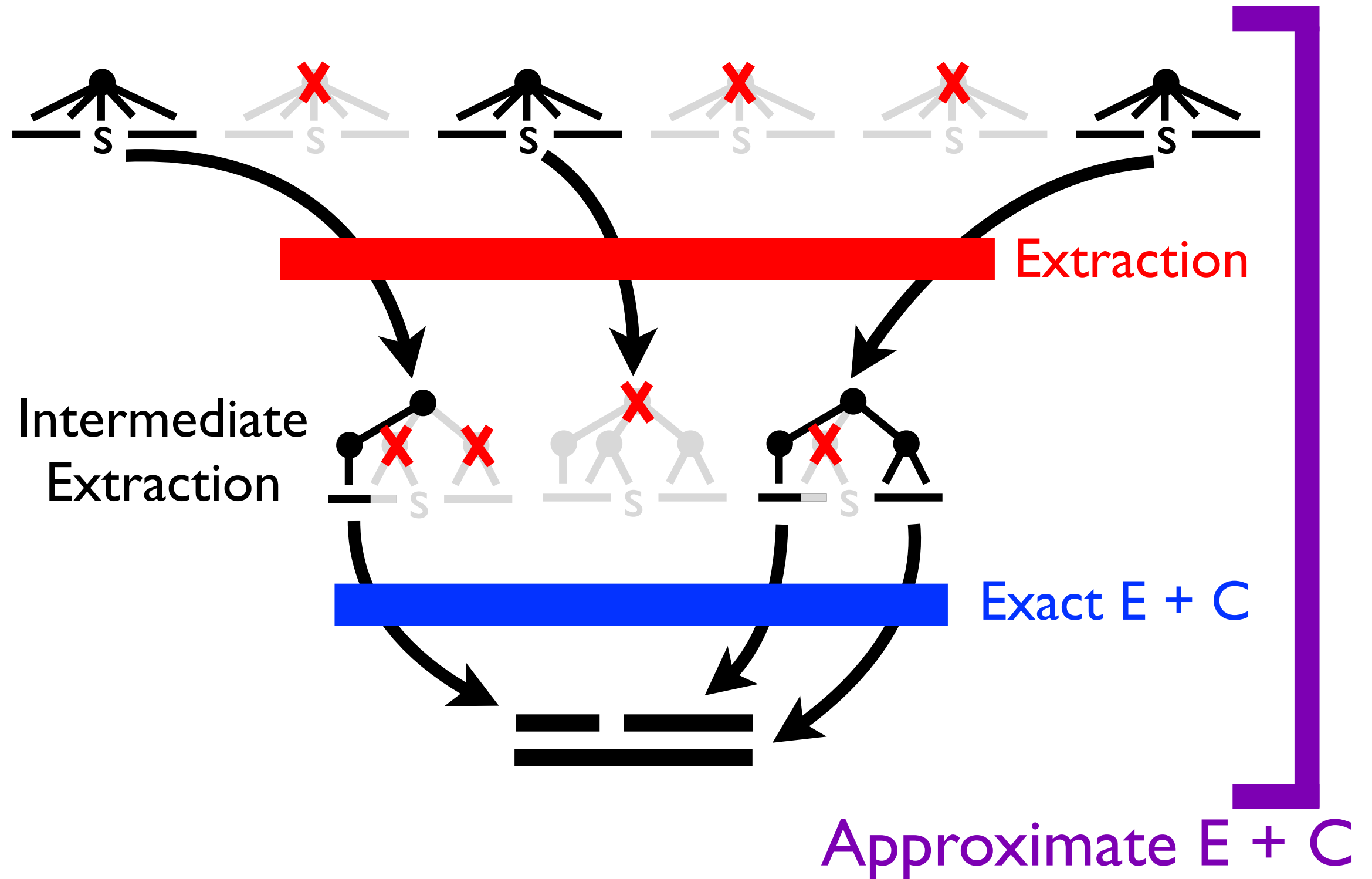


# Coarse-to-fine Inference

---



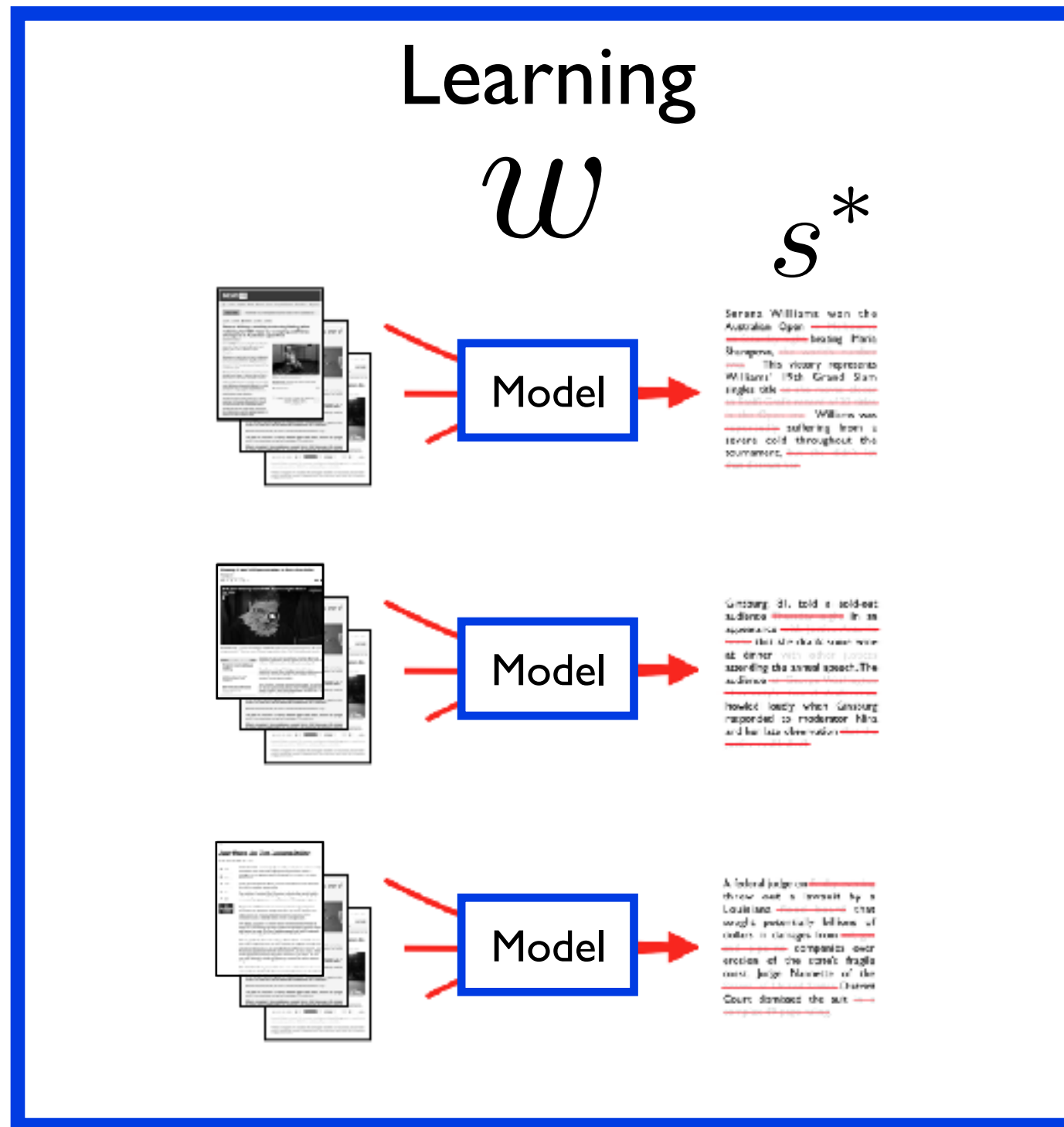
# Coarse-to-fine Inference





Learning  $\mathcal{W}$

# Learning to Summarize



# Learning to Summarize

---

Structured SVM Training:

$$\min_w \quad \|w\|_2^2$$

s.t. for all summaries  $s \neq s^*$ :

# Learning to Summarize

---

Structured SVM Training:

$$\min_{w, \xi} \left[ \|w\|_2^2 + \xi \right]$$

s.t. for all summaries  $s \neq s^*$ :

$$w^\top f(s^*) \geq w^\top f(s) + \text{loss}(s^*, s) - \xi$$

Model score of human summary    Model score of guess summary    Comparison of guess and human summary

# Learning to Summarize

---

Structured SVM Training:

$$\min_{w, \xi} \left[ \|w\|_2^2 + \xi \right]$$

s.t. for all summaries  $s \neq s^*$ :

$$w^\top f(s^*) \geq w^\top f(s) + \text{loss}(s^*, s) - \xi$$

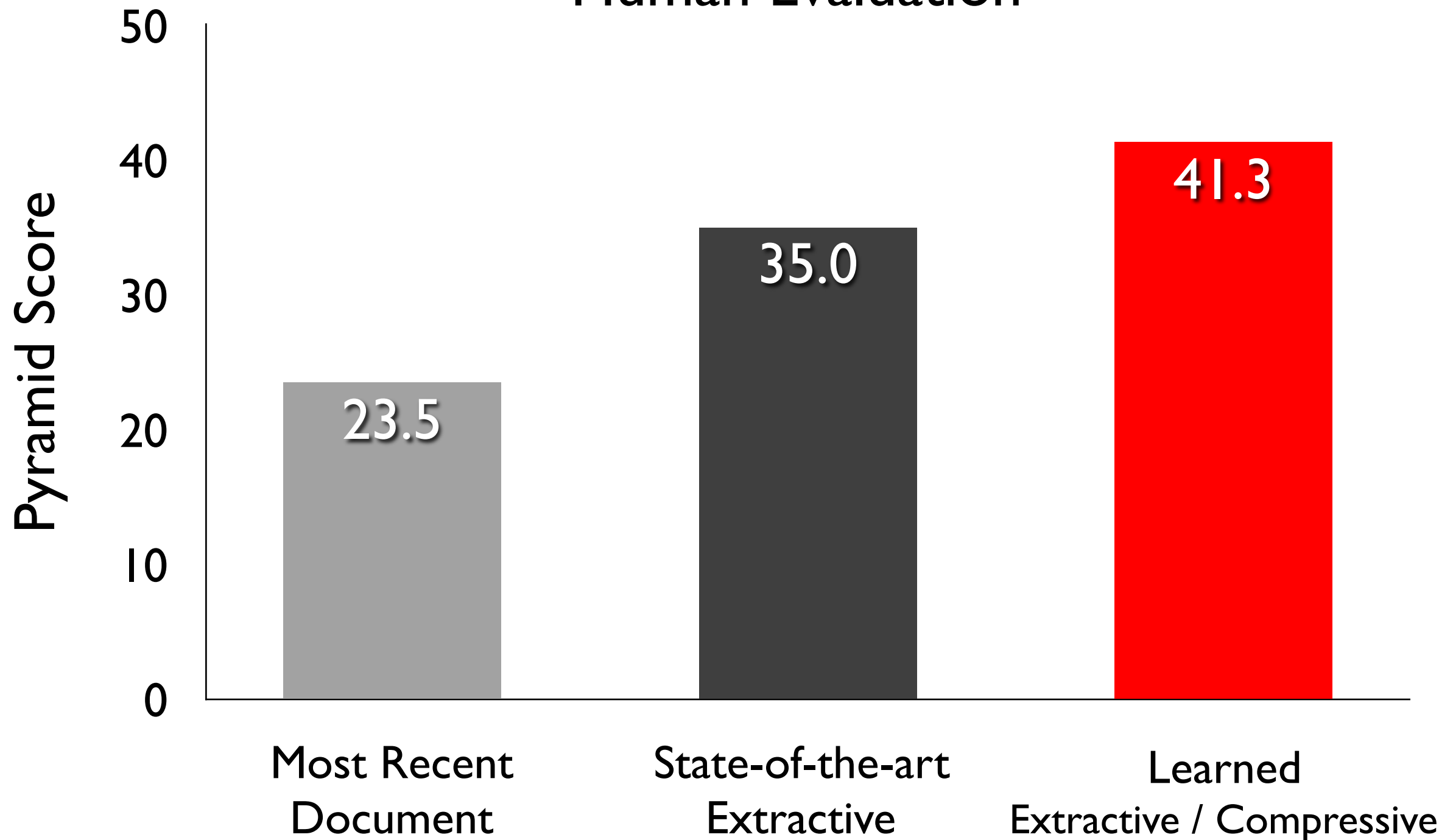
Exponentially many constraints!

# Experiments

# Results

---

## Human Evaluation





# Summarizer Output Example

---

## Summary of 93 articles

A massive dust storm descended on the Phoenix area on Tuesday night drastically reducing visibility and delaying flights as strong winds toppled trees and caused power outages for thousands of residents in the valley. The National Weather Service says strong winds with gusts of more than 60 mph were moving northwest through Phoenix. The wall of dust moved across the desert from the south. The dust cloud was 50 miles wide and the storm left over 8,000 customers without power.

$\leq$   
80 words

# Summarizer Output Example

---

## Summary of 93 articles

A massive dust storm descended on the Phoenix area on Tuesday night drastically reducing visibility. The wall of dust moved across the desert from the south on Tuesday. Thousands of people were left without power after strong winds toppled trees.

$\leq$   
40 words

# Summarizer Output Example

---

## Summary of 93 articles

A massive dust storm descended on the Phoenix area drastically reducing visibility and delaying flights as strong winds toppled trees.

$\leq$   
20 words