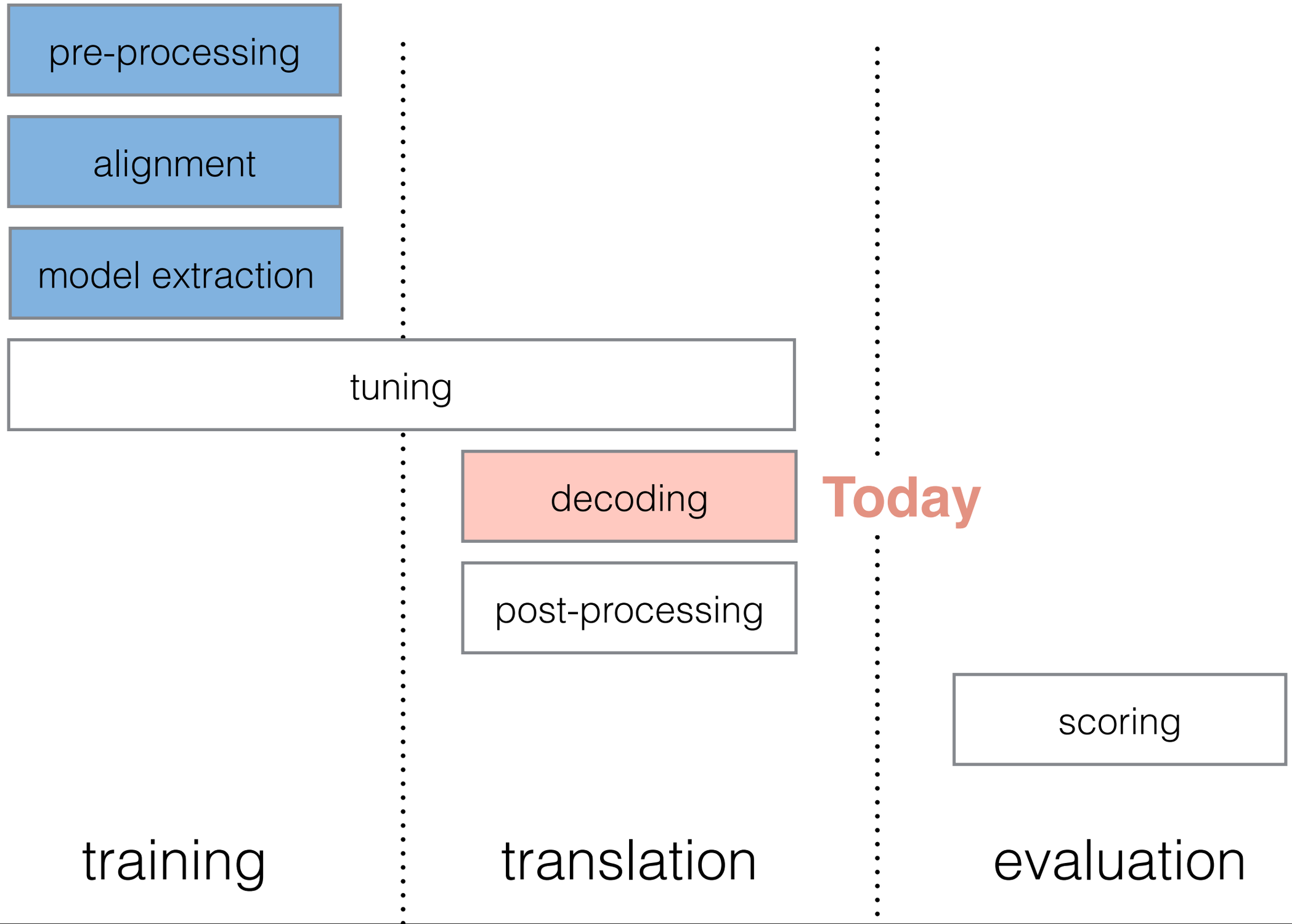
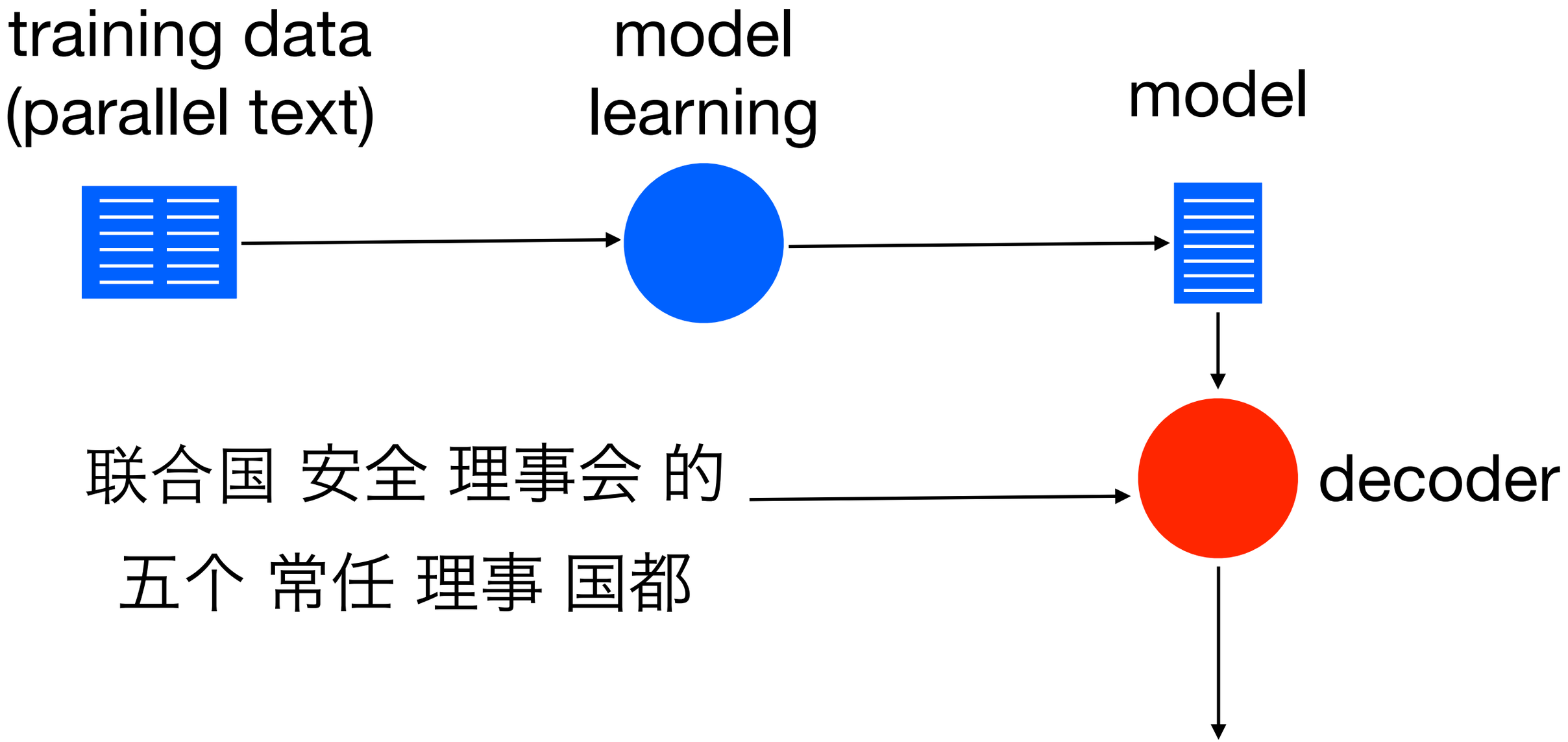
Administrative

- Homework 2: due a week from tomorrow
- Leaderboard will be up soon

Big Picture


pre-processing
alignment
model extraction
tuning
decoding
post-processing
Today
scoring
training
translation
evaluation


training data
(parallel text)
model
learning
model
联合国 安全 理事会 的
五个 常任 理事 国都
decoder
However , the sky remained clear
under the strong north wind .

Decoding Review

- Given a model, we want to find the solution to

$$e^* = \underset{e}{\textbf{argmax}}\, p(e \mid f)$$

- Dynamic programming provides the approximation

$$(e^*, a^*) = \underset{e,a}{\textbf{argmax}}\; p(e, a \mid f)$$

Factored search

- Translate a word (or phrase) at a time
- Assemble English translation left-to-right
- Maintain a data structure that records these
  - Sentence: *Yo tengo hambre*

generated English

coverage vector

- Example hypothesis creation:

old hypothesis | add word | new hypothesis

- translation model: trivial case, since all the words are translated independently

$$\text{hypothesis.score} \mathrel{+}= \log P_{TM}(\text{am} \mid \text{tengo})$$

- a function of just the word (or phrase) that is added

- Example hypothesis creation:

old hypothesis | add word | new hypothesis

- language model: still easy, since (bigram) language models depend only on the previous word

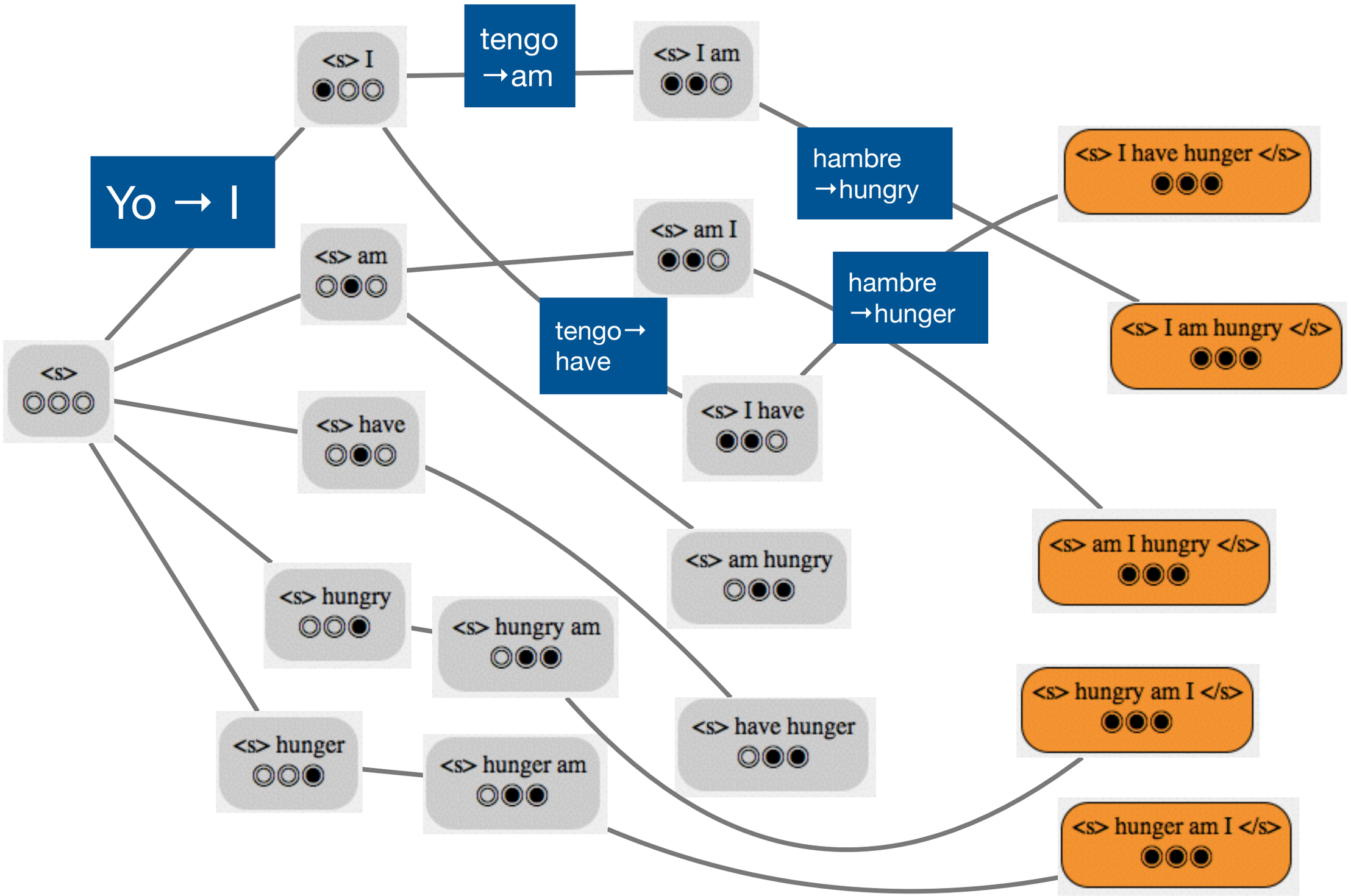
$$\text{hypothesis.score} \mathrel{+}= P_{LM}(\text{am} \mid \text{I})$$

- a function of the old hyp. and the new word translation

- These items can then be arranged into a **search graph** representing the whole translation space

- Component models need to factorize over this graph

Input *Yo tengo hambre*



Algorithm

- Start with a list containing the empty hypothesis
- Loop
  - For each hypothesis
    - For each remaining untranslated word
      - Extend the hypothesis with the word
      - Add to the list of hypotheses

Demo

Full search, no dynamic programming

Dynamic programming

- All submodels factorize into lattices where only local information is needed

- **Recombination**: chart items that are the same with respect to dynamic programming state can be combined

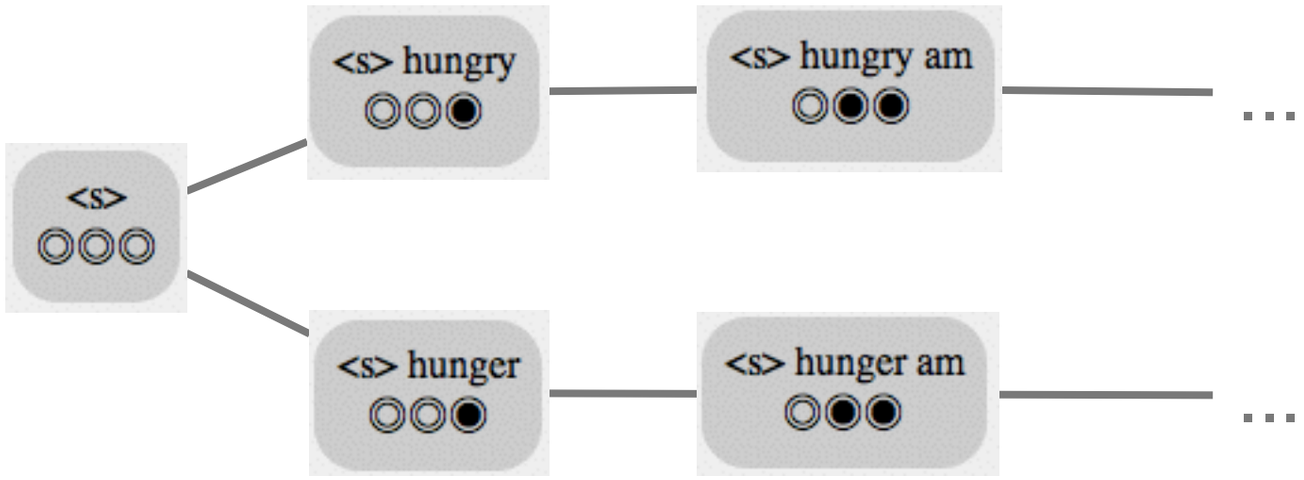
- Backpointers allow the full translation to be recovered

- Notice anything here?

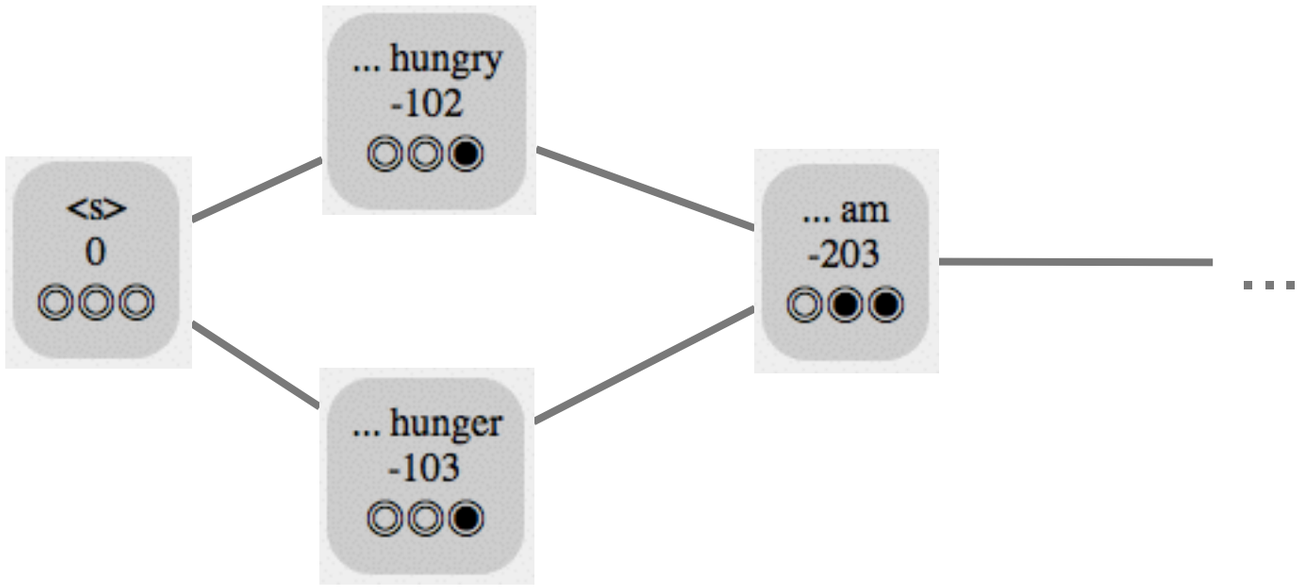
- (1) <s> is never used in computing the scores AND
  (2) <s> is implicit in the graph structure

- Why are we lugging these old words around?

- Before



- After



The score of the new hypothesis is the highest-scoring way to produce it

Dynamic Programming

- Start with a list containing the empty hypothesis
- Loop
    - For each hypothesis
        - For each remaining untranslated word
            - Extend the hypothesis with the word
            - Add to the list of hypotheses if (a) no equivalent item exists or (b) this one has a higher score

Demo

Dynamic programming

DP State

- What is an “equivalent hypothesis” (or item)?
  - An item that matches on all shared state
    - coverage vector
    - previous word (needed for LM)
- In general, the items will also cache the score of the Viterbi path to that point, and maintain a list of pointers to all incoming tail nodes

Stack decoding

- There are still too many hypotheses
- Also, all hypotheses are in competition:
  - Search expansion that always extends the lowest-scoring item will waste lots of time
- Stack decoding groups items by coverage vectors

Stack decoding

- Start with a list containing the empty hypothesis
- Loop
    - For each stack
        - For each hypothesis
            - For each remaining untranslated word
                - Extend the hypothesis with the word
                - Add hypothesis to the right stack group

Pruning

- There are still too many hypotheses
- We can prune the stacks in many ways:
  - **Histogram pruning**: limit stacks to size *N*
  - **Threshold pruning**: remove hypotheses with a score ε below the highest-scoring item in the stack

Stack decoding

With pruning

- Start with a list containing the empty hypothesis
- Loop
    - For each stack
        - For each hypothesis
            - For each remaining untranslated word
                - Extend the hypothesis with the word
                - Add hypothesis to the right stack group
                - Prune

Demo

"Stack" decoding with beam search

Distortion limits

- There are still too many hypotheses

- Distortion limits restrict the set of source language words that can be used to extend a hypothesis to those with *d* words

Stack decoding

With pruning, distortion limits

- Start with a list containing the empty hypothesis
- Loop
    - For each stack
        - For each hypothesis
            - For each remaining *eligible* untranslated word
                - Extend the hypothesis with the word
                - Add hypothesis to the right stack group
                - Prune

- With these innovations, decoding has been reduced to linear time (in the sentence length)

- Types of errors:
  - search: approximations preclude model-best translation
  - model: highest-scoring translation is not the actual best translation

Important concepts

- Decoding as graph search
- Stack decoding and dynamic programming
- Factorized models for edge scoring
- Pruning (histogram, threshold)