Natural Language Processing (CS-472) Spring-2023

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Overview of this week's lecture

Coreference Resolution

- Introduction to Coreference Resolution
- Coreference resolution approaches
  - Using mention-pair
  - Using mention-pair ranking
  - Using clustering
- Coreference resolution evaluation

Coreference resolution means resolving coreference

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Coreference resolution can be tricky even for humans

The Islamabad High Court on Thursday barred FIA) from arresting Suleman Shehbaz, the son of Prime Minister Shehbaz Sharif, who is expected to return to Pakistan this week after four years of self-exile in London.

Suleman is living in London with his family. He had filed a plea before the IHC a day ago, seeking protective bail that would enable him to surrender before a trial court.
The court took up the plea for hearing today. Suleman’s counsel Amjad Pervez appeared before the court.
During the proceedings, IHC Chief Justice Aamer Farooq issued directives for the applicant, asking him to surrender before the court by Dec 13 and barred the FIA from arresting him until then. Justice Farooq said it was necessary for an applicant to be present in the court while seeking protective bail.

Pervez told the court that his client was returning to the country on Sunday. “He wants to appear before the relevant authorities,” he added. The counsel said the court had been granting similar protective bails in the past.

Following the arguments, the court granted them relief.

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Split Antecedent

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- To fully understand natural language.
    - Information extraction.

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Who was living in London for the last four years?

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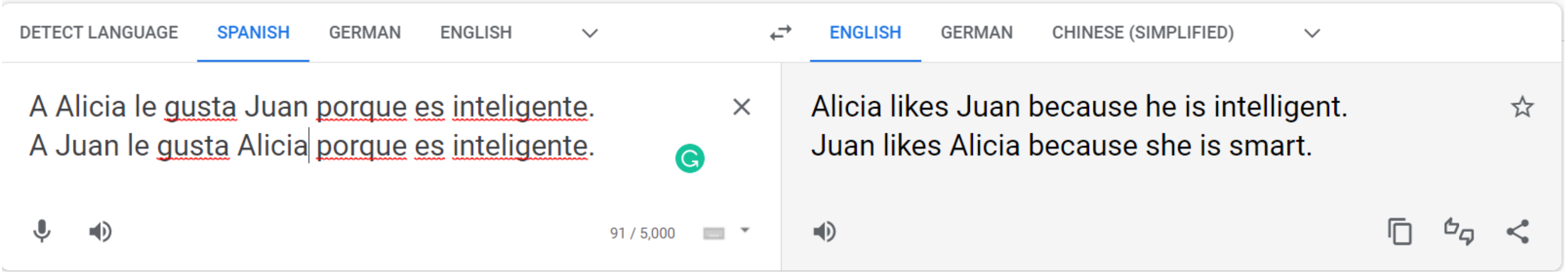

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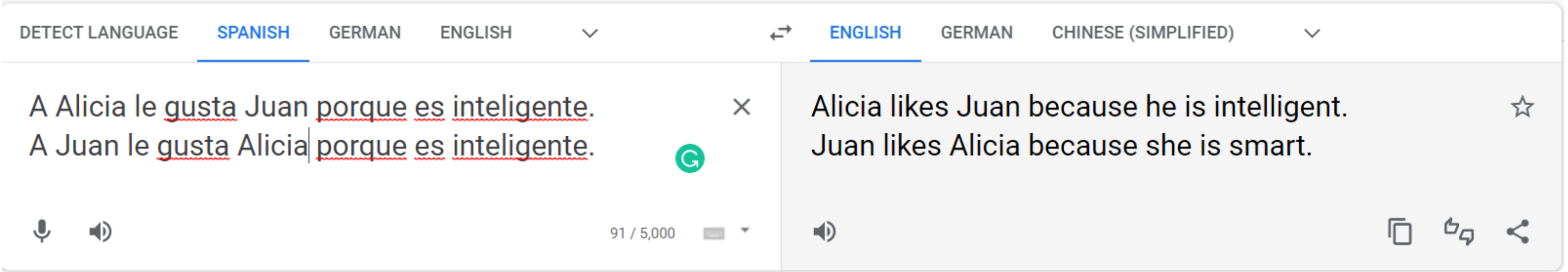

  - Dialogue Generation

Human: Book tickets to see James Bond.
Bot: Spectre is playing near you at 02:00 and 05:00. How many tickets would you like?
Human: Two, for showing at five.

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- Detect the mentions.

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“[I] voted for [John Doe] because [he] was most aligned with [[my] values]”, [she] said.

Coreference resolution is performed in two steps

- Detect the mentions.
  - Mentions can be nested.
- Cluster the mentions.
  - Which mention is coreferent to what other mention.

"[I] voted for [John Doe] because [he] was most aligned with [[my] values]", [she] said.

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  - Noun Phrases “A dog”, “the big fluffy cat struck in the tree”

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- Detecting different types of mentions using separate methods serves as a pre-processing step.
- You can also train a classifier that runs on the text and detects all types of mentions.
- You can also perform mention detection and coreference resolution simultaneously in end-to-end manner.
    - More on this in coming slides.

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    - *No student* got an A Grade. (Is *no student* any reference?)
    - *Every student* got an A Grade. (Is *every student* a clear and concrete reference?)
    - The best teacher in the word. (Unclear. May or may not be)
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  - Keep all mentions as candidate mentions and after clustering remove singletons.

Let’s learn just a tiny bit of linguistics

- Coreference is when two mentions refer to the same entity in the world.
    - “***Donald Trump’****s twitter account reinstated.* ***Trump*** *was banned from twitter in January 2021 after January 6 capitol riots*”.
        - Both Donald Trump and Trump refer to the same entity but both mentions can be understood and interpreted independently of each other.

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- Anaphora is a related linguistic concept where a term (anaphor) refers to another term (antecedent) for interpretation.
  - **Trump** reacted to reactivation of **his** twitter account by saying **he** wouldn’t be quickly returning to twitter.

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  Antecedent Anaphor Anaphor
- The concept of anaphors (and cataphors, coming soon) is not widely used in NLP.

Let’s learn just a tiny bit of linguistics (continued)

- Barak Obama visited Florida. During the visit, Obama said his government will increase budget for health.

Text

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Real World

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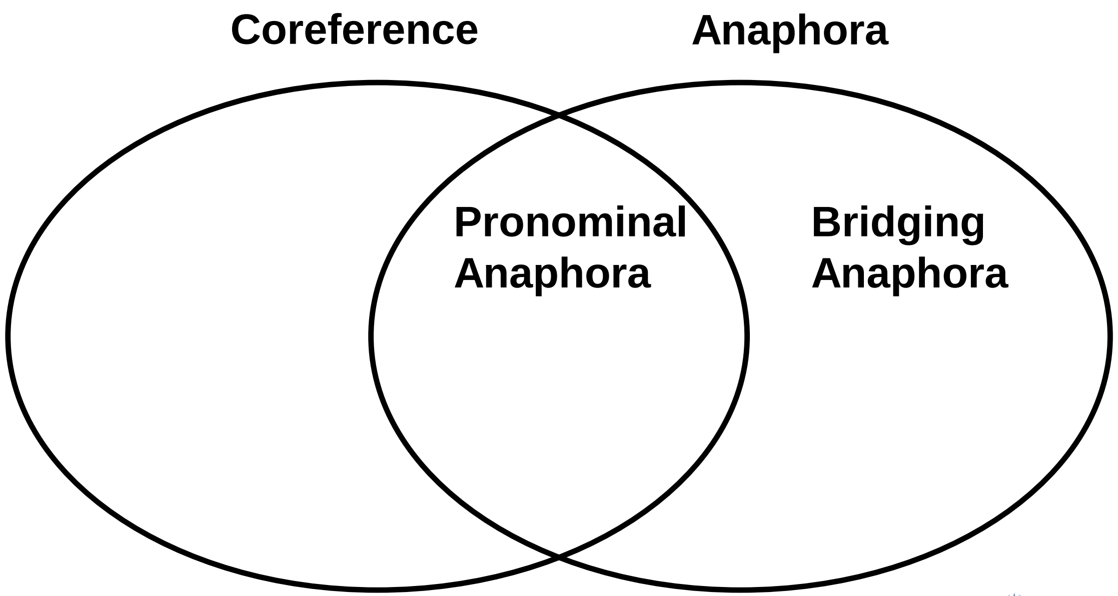
- We went to see the match. The tickets were already sold.
  - This is a bridging anaphora.



Anaphora vs Cataphora

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- In NLP also, the position of antecedent is not paid much attention to.

  - NLP systems only look back to find the textual reference (antecedent).

Sometimes knowledge of the world in important to resolve coreference

- She poured water from the pitcher into the cup until it was full.

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Sometimes knowledge of the world in important to resolve coreference

- She poured water from the pitcher into the cup until it was full.
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"If you have fully solved coreference, arguably you have fully solved AI."

Hector J. Levesque

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Levesque, Hector J. "On our best behaviour." Artificial Intelligence 212 (2014): 27-35.

- Take pairs of mentions and train a binary classifier to classify whether the pair is coreferent or not.

"I voted for John Doe because he was most aligned with my values", she said.

I | **John Doe** | **He** | **My** | **She**

Cluster 1
Cluster 2

Coreference Model: Mention Pair

- Take pairs of mentions and train a binary classifier to classify whether the pair is coreferent or not.
  - The classifier assigns every pair of mentions a probability $p(m_i, m_j)$.
  - Read the text from left to right.
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What about clustering?

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- Pick a threshold, say 0.5, and add reference links between mentions where $p(m_i, m_j)$ is higher.

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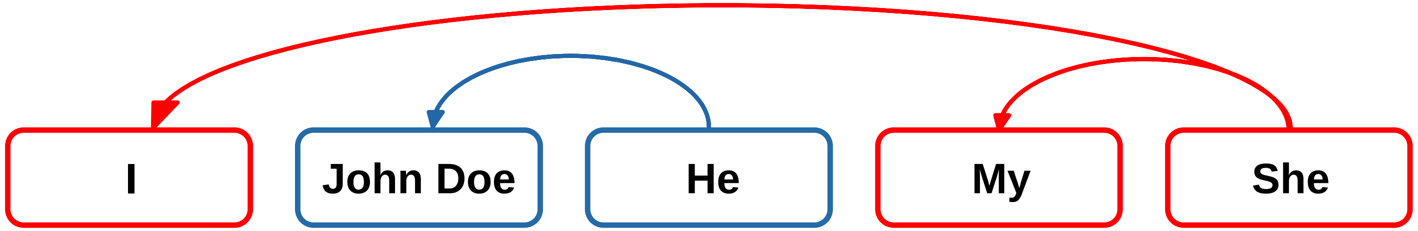

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Coreference Model: Mention Pair Test Time

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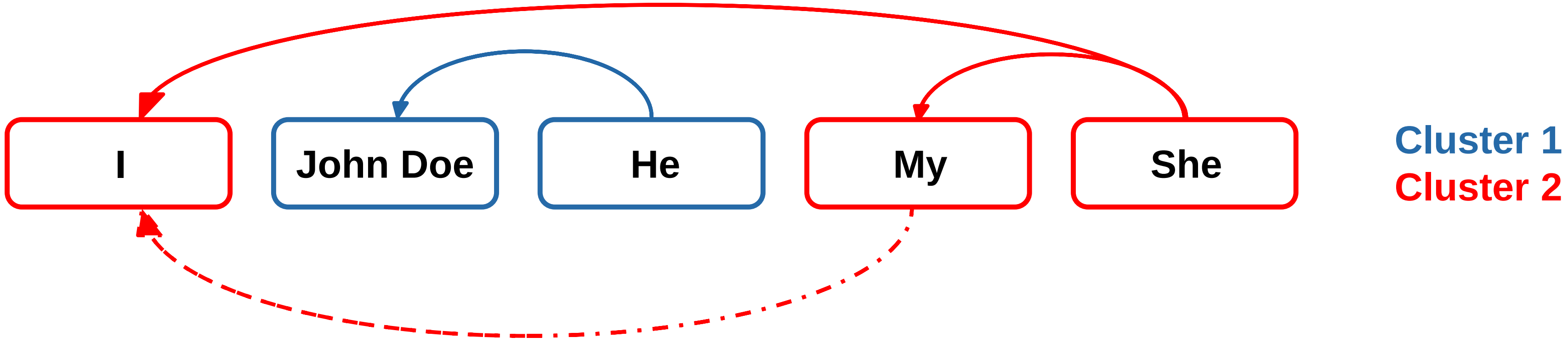

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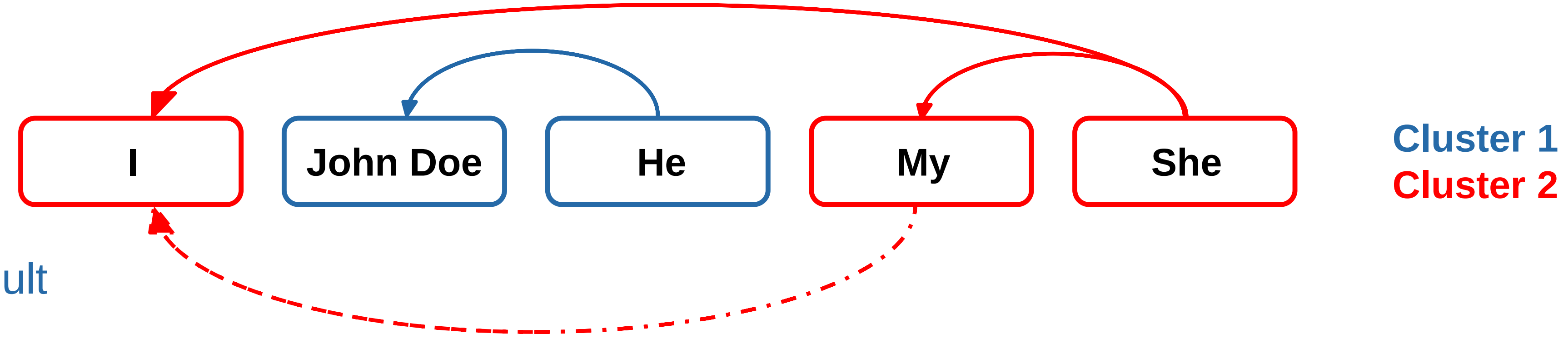

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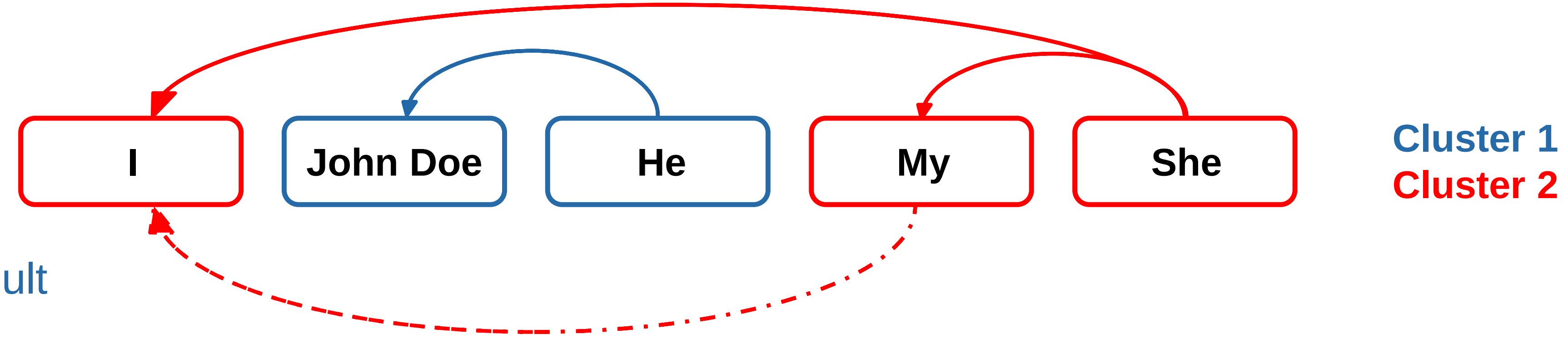

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- Disadvantage: The mention-pair model does not work well for longer documents.
  - Many mentions only have one clear antecedent but mention-pair model tries to identify all of them.
  - Solution: Train the model to predict only one antecedent per mention.

Coreference Model: Mention Ranking

- Assign each mention its highest ranking candidate antecedent.
  - What's the best antecedent for She?

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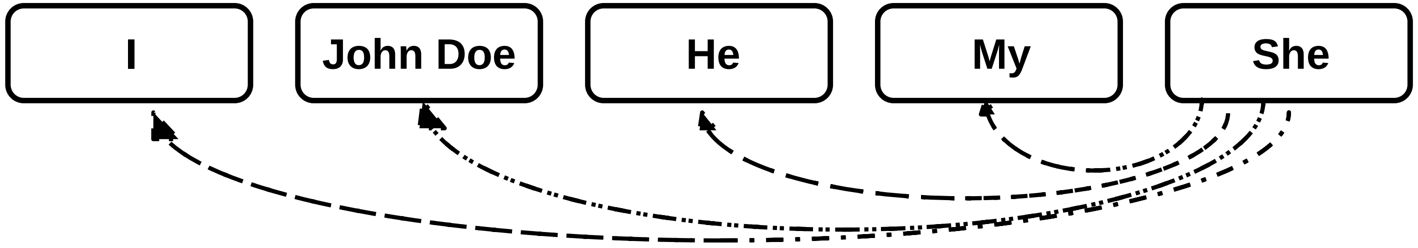

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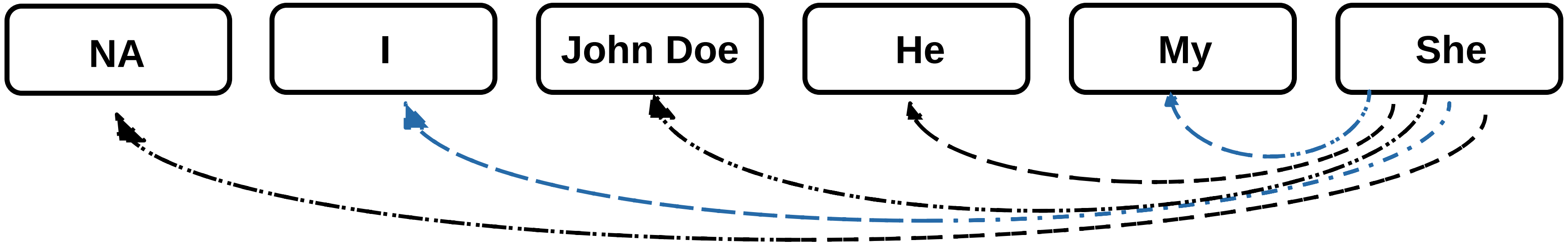

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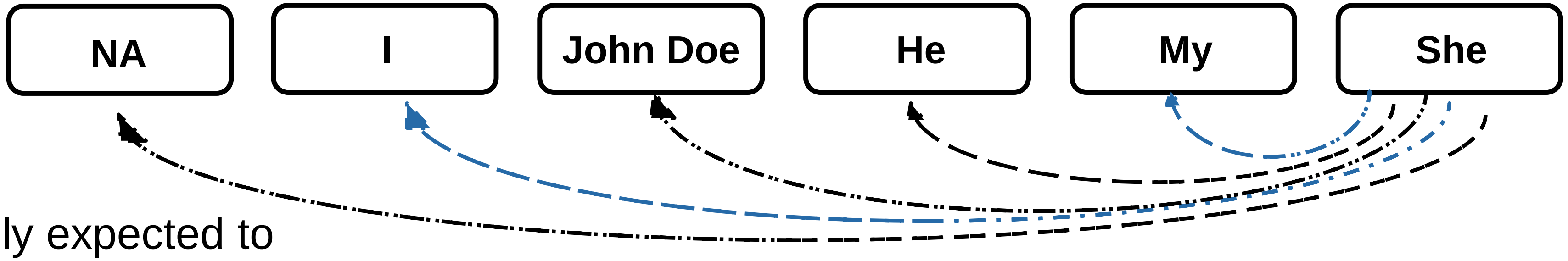

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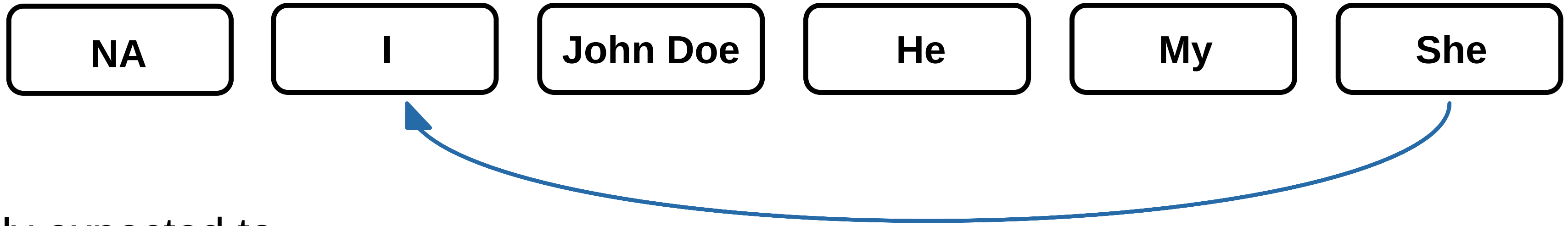

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- Add only the highest scoring coreference link.

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Coreference Model: Training Mention Ranking

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- Current mention m_j should be linked to any one of the candidate antecedents it's coreferent with.

- The loss function will be

Maximise this probability

$$J = \sum_{i=2}^{N} -\log\left(\overbrace{\sum_{j=1}^{i-1} \mathbb{1}(y_{ij} = 1)p(m_j, m_i)}\right)$$

Iterate through candidate antecedents

for ones that are coreferent to m_j

and assign them high probability

  - Producing high probability with any one of candidate antecedents will result in overall high probability.

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- Current mention m_j should be linked to any one of the candidate antecedents it's coreferent with.

- The loss function will be

$$J = \sum_{i=2}^{N} - \log \left(\overbrace{\sum_{j=1}^{i-1} \mathbb{1}(y_{ij} = 1) p(m_j, m_i)}^{\text{Maximise this probability}} \right)$$

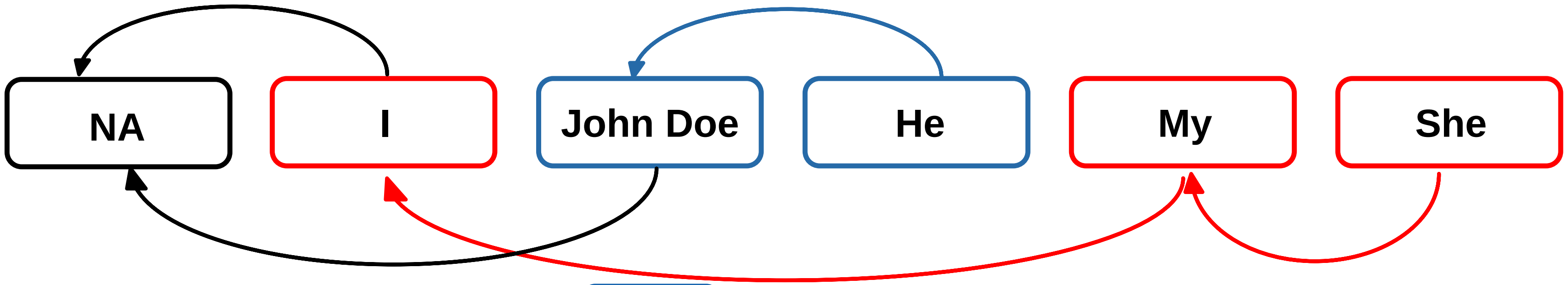
Iterate through candidate antecedents

for ones that are coreferent to m_j

and assign them high probability

  - Producing high probability with any one of candidate antecedents will result in overall high probability.

- During Test



Coreference Model: Clustering Based

- Use a clustering algorithm from the beginning to clusters all detected mentions.
    - Each cluster represents an entity.

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    - Euclidian Distance
    - Cosine Similarity
    - Neural Networks

Clark, Kevin, and Christopher D. Manning. "Improving coreference resolution by learning entity-level distributed representations." arXiv preprint arXiv:1606.01323 (2016).

Clustering-based coreference models make easy decisions first

Google recently, …, **the company** announced **Google Plus**, …, **the product** features …

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Google

The company

Google Plus

The product

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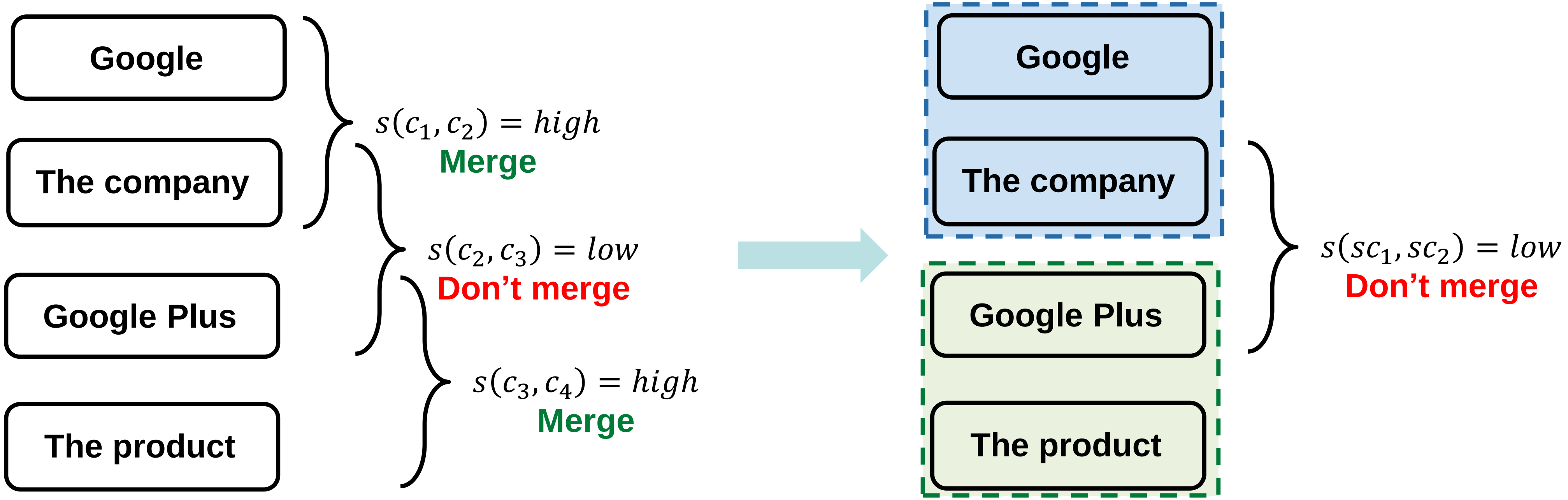
$s(c_1, c_2) = high$
Merge

$s(c_2, c_3) = low$
Don't merge

$s(c_3, c_4) = high$
Merge

Clustering-based coreference models make easy decisions first

Google recently, …, **the company** announced **Google Plus**, …, **the product** features …



Many evaluation metrics exist for coreference resolution.

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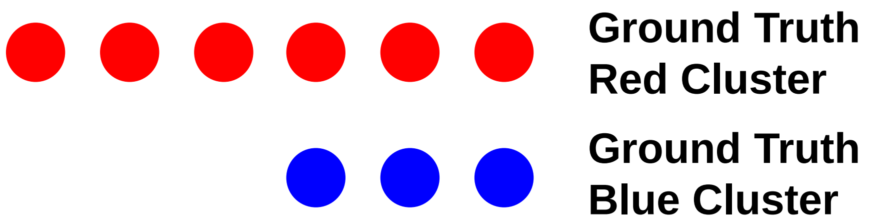

Bagga, Amit, and Breck Baldwin. "Entity-based cross-document coreferencing using the vector space model." COLING 1998 Volume 1: The 17th International Conference on Computational Linguistics. 1998.

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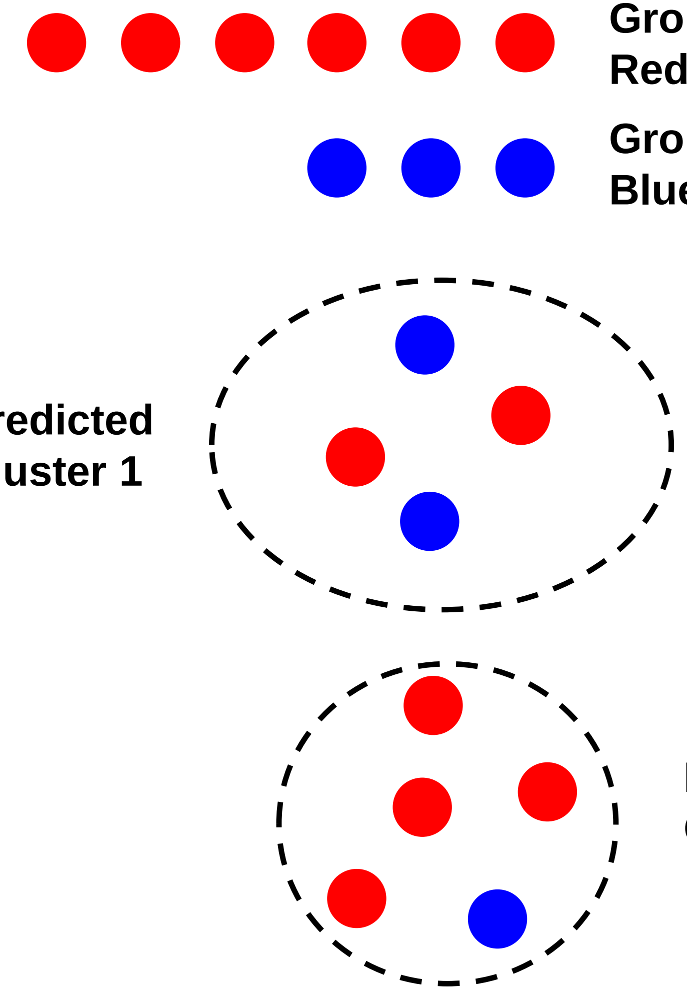

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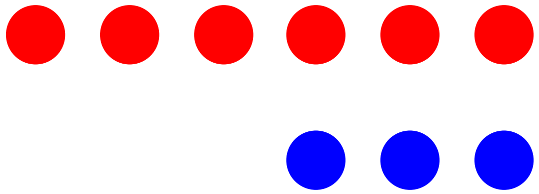
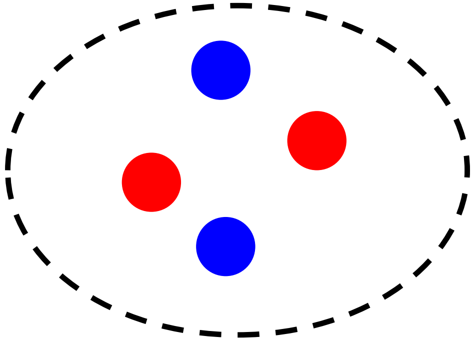


Ground Truth Red Cluster

Ground Truth Blue Cluster

Predicted Cluster 1



$$Prec_{Red} = \frac{2}{4}$$

$$Recall_{Red} = \frac{2}{6}$$

$$Prec_{Blue} = \frac{2}{4}$$

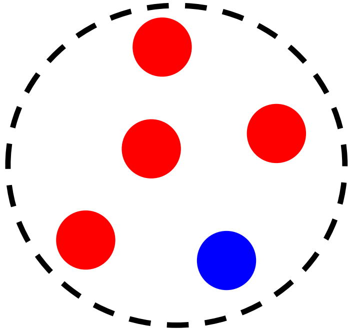
$$Recall_{Blue} = \frac{2}{3}$$

$$Prec_{Red} = \frac{4}{5}$$

$$Recall_{Red} = \frac{4}{6}$$

$$Prec_{Blue} = \frac{1}{5}$$

$$Recall_{Blue} = \frac{1}{3}$$



Predicted Cluster 2

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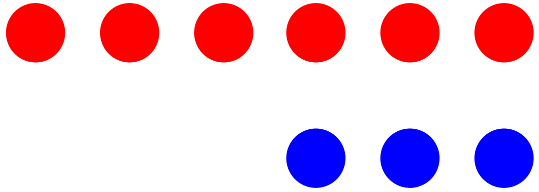
$$Weighted\ Precision = \frac{\left[4\frac{4}{5} + 1\frac{1}{5} + 2\frac{2}{4} + 2\frac{2}{4}\right]}{9} = 0.6$$



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Ground Truth Blue Cluster

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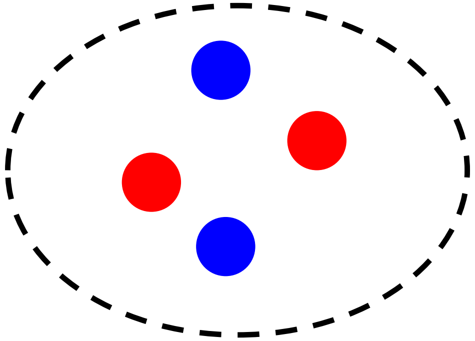

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$$Recall_{Blue} = \frac{2}{3}$$

$$Prec_{Red} = \frac{4}{5}$$
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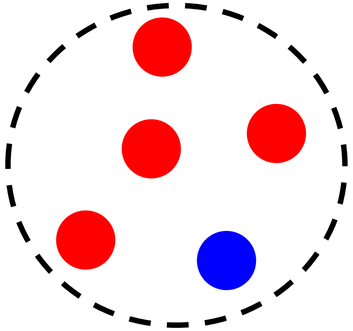
$$Recall_{Blue} = \frac{1}{3}$$



Predicted Cluster 2

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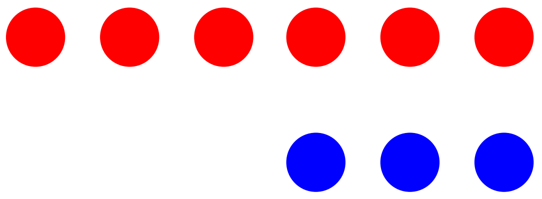
Ideally a predicted cluster should be complete and homogenous



Ground Truth Red Cluster

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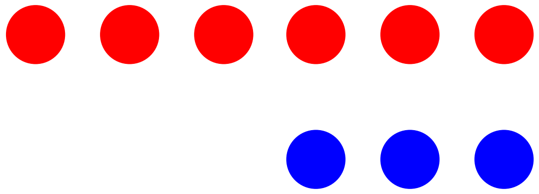
Ideally a predicted cluster should be complete and homogenous

- **Homogeneity:** A predicted cluster is homogenous if it all of its members belong to one ground truth cluster.



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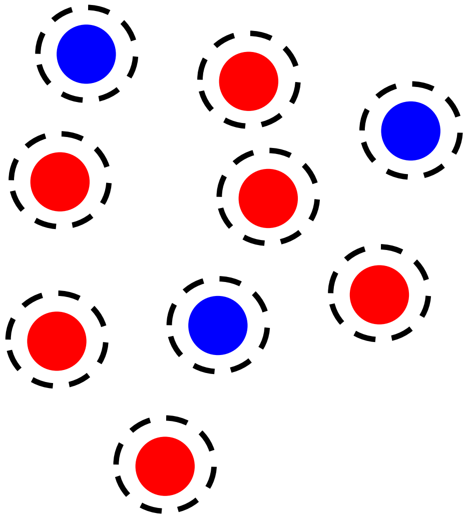

$$Prec_{Blue} = \frac{1}{1}$$

$$Recall_{Blue} = \frac{1}{3}$$

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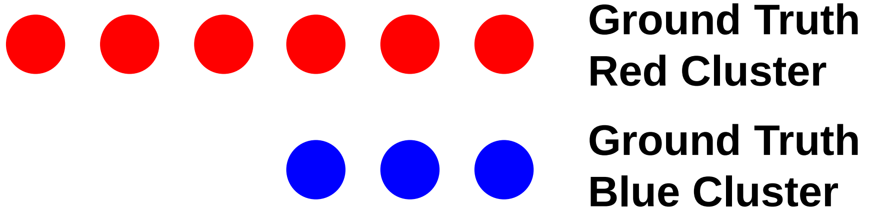
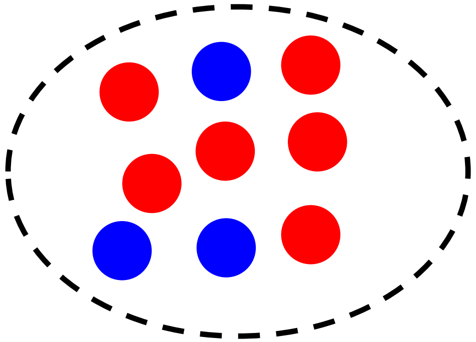
Ideally a predicted cluster should be complete and homogenous

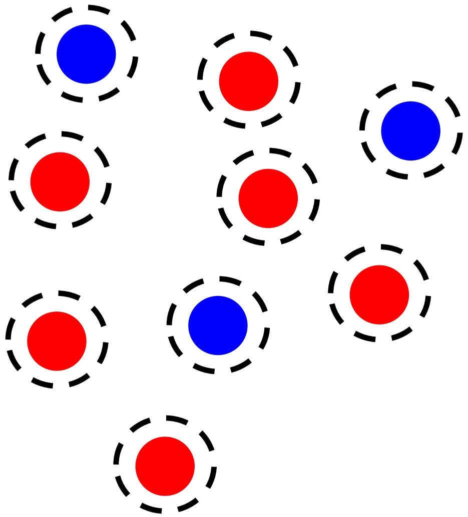
- **Homogeneity:** A predicted cluster is homogenous if it all of its members belong to one ground truth cluster.

- **Completeness:** A predicted cluster is complete if it contains all members of a ground truth cluster.



$$Prec_{Blue} = \frac{3}{9}$$
$$Recall_{Blue} = \frac{3}{3}$$





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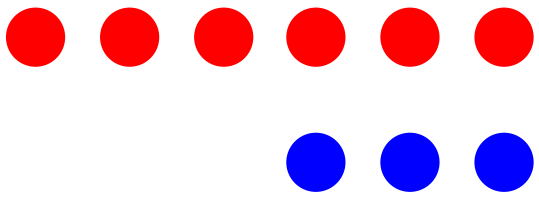
Ideally a predicted cluster should be complete and homogenous

- **Homogeneity:** A predicted cluster is homogenous if it all of its members belong to one ground truth cluster.

- **Completeness:** A predicted cluster is complete if it contains all members of a ground truth cluster.

- Balance between homogeneity and completeness of predicted clusters should be maintained.



Ground Truth Red Cluster

Ground Truth Blue Cluster

$$Prec_{Blue} = \frac{3}{9}$$
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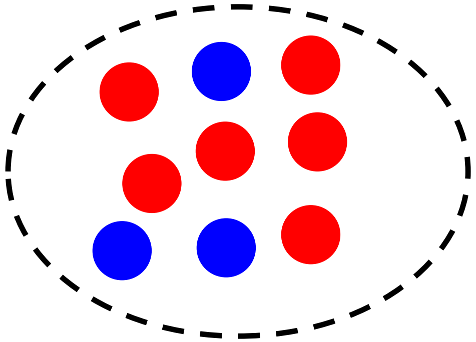

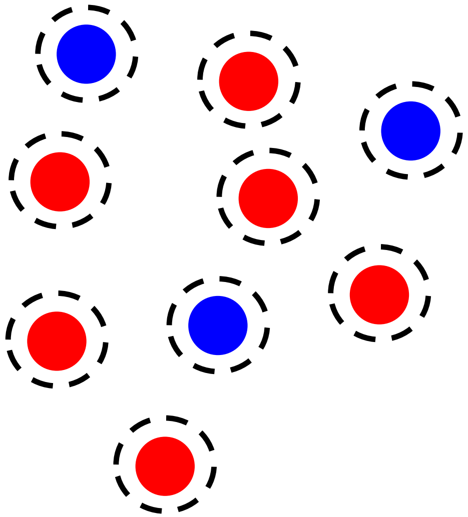

$$Prec_{Blue} = \frac{1}{1}$$
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Do you have any problem?

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