Knowledge-Augmented Methods for Natural Language Processing

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Knowledge in NLP

- A language model (LM) learns **how to express**

  I go school to to want. ✗

  I want to go to school. ✓

- Knowledge indicates **what to express**

  Q: Where is the painting **Mona Lisa**?

  A: It is in **Louvre, Paris**.

Integrate Knowledge into LM

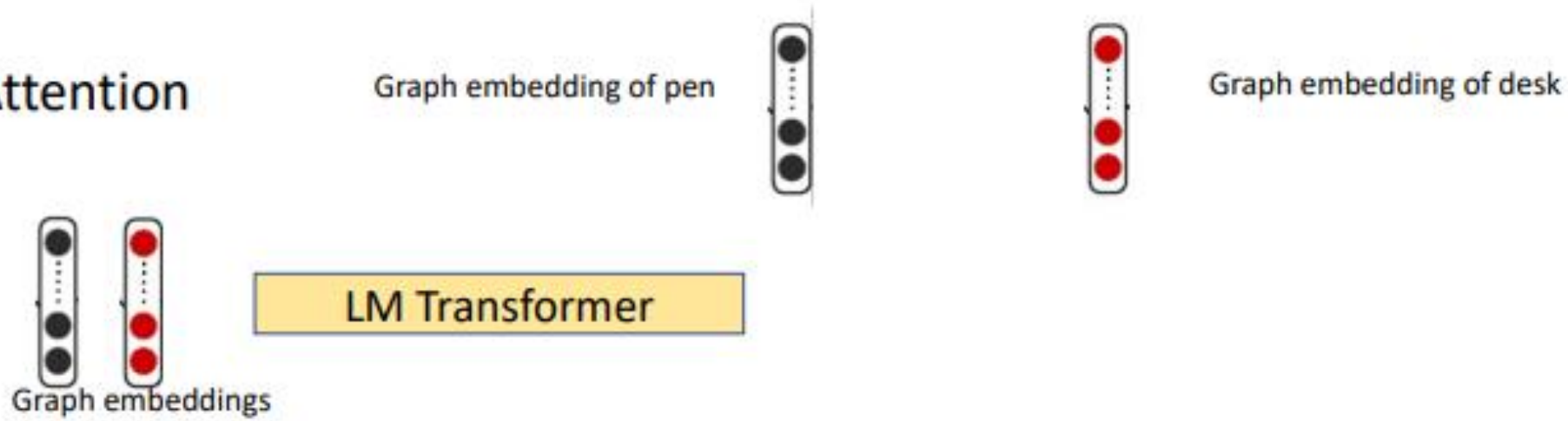
- **Fuse** knowledge representation into language model
  - Concatenate concept names/descriptions into input

The pen is on the desk. [SEP] desk: a table, …

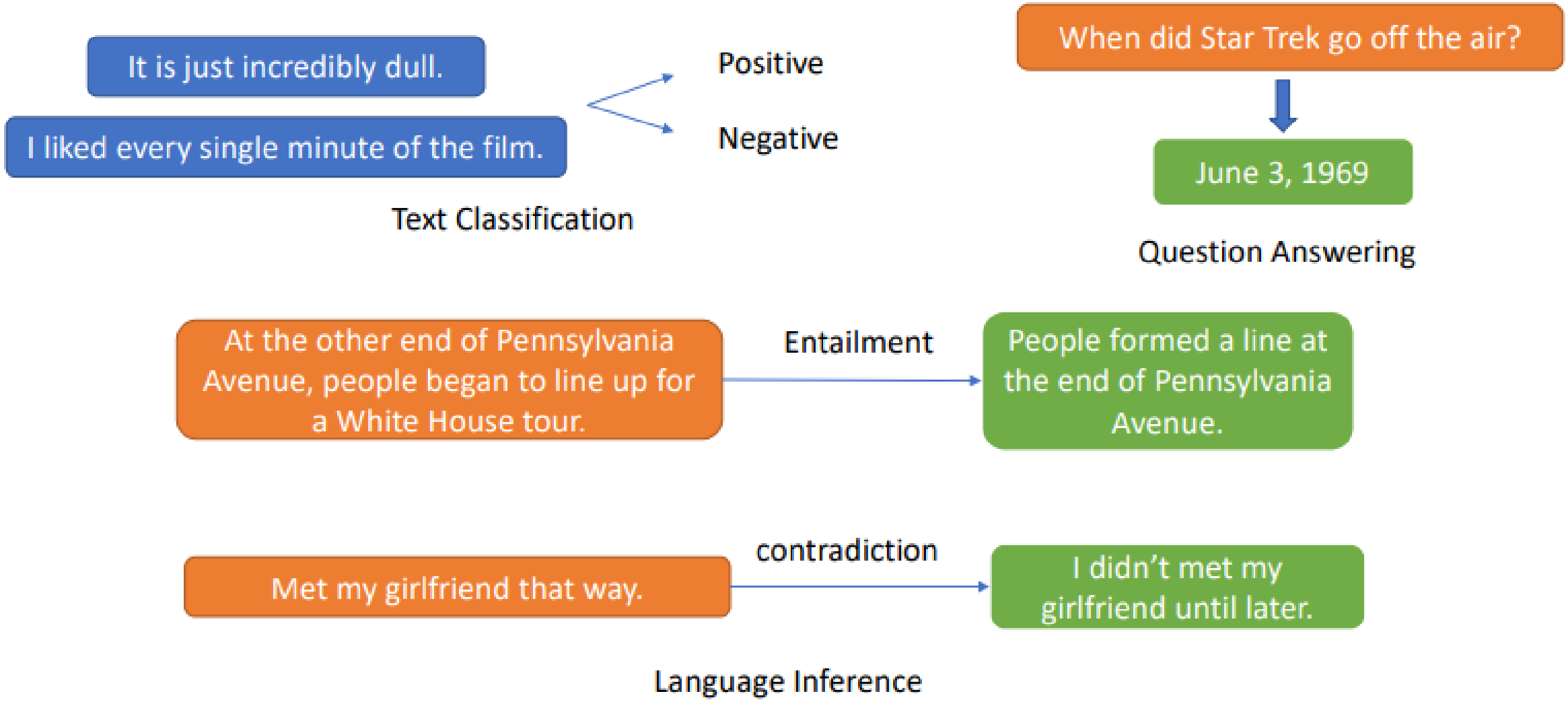
  - Append/add concept embeddings into input embeddings

The pen is on the desk.

  - Attention



Natural Language Understanding



Natural Language Understanding with Knowledge

2016 Tour de France had a total of 198 musicians.

Shut Up is a song by Stormzy.

True

False

Fact Verification

When did Star Trek go off the air?

June 3, 1969

Question Answering

Kepulauan Sula — Country → Indonesia

Jerome Kersey — member of sports team → Portland Trail Blazers

Slot Filling/Knowledge Graph Completion

Cyclone Taylor , a professional ice hockey forward who led the [START_ENT] Vancouver Millionaires [END_ENT]

Entity Linking

Tasks and Benchmarks

- Question Answering
  - Open-Domain QA: Questions that requires external knowledge
    - NaturalQuestions (Kwiatkowski et al., 2019)
      What was the first capital city of Australia? -> Melbourne.
  - Commonsense QA: Questions that requires commonsense
    - CommonsenseQA (Talmor et al., 2018)
      What do all humans want to experience in their own home?
      👍 feel comfortable, 👎 work hard, 👎 fall in love, 👎 lay eggs, 👎 live forever

Three Slides: Knowledge in NLP

- **Augment Knowledge for What? (a) Natural Language Understanding**
  - Information Extraction: NER, Entity linking, Slot filling, Relation prediction, Fact verification
  - Question answering: Open-domain QA, Commonsense QA, Knowledge-base QA
- **Obtain Knowledge from Where?**
  - Wiki-based: Wikipedia, WikiData, Wiktionary
  - General domain: Freebase, DBpedia, YAGO
  - Specific domains: UMLS, ArnetMiner, DBLP
  - Commonsense: OMCS, ConceptNet
- **Use Knowledge via How?**
  - Entity linking based methods
    - ERNIE (ACL'19), KEAR (IJCAI'22), EaE (EMNLP'20), FILM (ACL'21), K-BERT (AAAI'20)
  - Retrieval based methods
    - DPR (EMNLP'20), REALM (ICML'20), REINA (ACL'22), RETRO ('21), WebGPT ('21)

Why knowledge is needed in NLG?

Question/Answer Generation (e.g., open-domain QA, question generation)

- Query: Who did Hawaii belong to before 1895?

Hawaiian Kingdom

Question-answer gap

Hawaii is the most recent state … **On Jan 17, 1895**. The United States Minister to the **Hawaiian Kingdom** conspired with U.S. citizens to overthrow the monarchy.

In 1895, United States Public Law acknowledged that "the overthrow of **Hawaiian Kingdom** occurred with the active participation of agents …

The **Hawaiian Kingdom**, or Kingdom of Hawaii, was a sovereign state located in the Hawaiian Islands formed in 1795.

Subject: **Hawaiian Kingdom**
Relation: end time
Object: **1895**

Three Slides: Knowledge in NLP

- **Augment Knowledge for What? (b) Natural Language Generation**
  - Question answering: Question generation and Answer generation
  - Dialog systems: Response generation
  - Reasoning: Explanation generation
  - Machine translation; Summarization; Paraphrasing
- **Obtain Knowledge from Where?**
  - Structured knowledge (Knowledge graph): WikiData, Freebase, DBPedia, YAGO, ConceptNet
  - Unstructured knowledge (Grounded document): Wikipedia, Wiktionary, ArnetMiner, OMCS
- **Use Knowledge via How?**
  - Knowledge graph based methods
    - GRF (EMNLP'20), CCM (IJCAI'18), MoKGE (ACL'22)
  - Grounded document based methods
    - RAG (NeurIPS'20), RE-T5 (ACL'21), CMR (ACL'19)

Do LMs have common sense? (masked LMs)

Birds usually can [MASK].

Masked LMs
(e.g., BERT)

Tigers usually have [MASK] **legs**.

LAMA (Petroni et al. 2019)

Prediction	Score	
Birds usually can **fly** .	33.1%	✅
Birds usually can **sing** .	8.2%	✅
Birds usually can **survive** .	3.5%	

NumerSense (Lin et al. 2020)

Prediction	Score	
Tigers usually have **two** legs .	14.1%	❌
Tigers usually have **short** legs .	11.2%	
Tigers usually have **four** legs .	8.8%	✅

(demo w/ AllenNLP) AllenNLP

Three Slides: Knowledge in NLP

- **Augment Knowledge for What? (c) Commonsense Reasoning**
  - "commonsense reasoning is a human-like ability to make presumptions about the type and essence of ordinary situations humans encounter every day."
  - Human-level AI
- **Obtain Knowledge from Where?**
  - Commonsense: OMCS, ConceptNet
- **Use Knowledge via How?**
  - KagNet (EMNLP'19), MHGRN (EMNLP'20), QA-GNN (NAACL'21)
  - GreaseLM (ICLR'22), GSC (ICLR'22)
  - CommonGen (EMNLP'20), KFCNet (EMNLP'21), KG-BART (AAAI'21), I&V (ICLR'22)
  - DrFact (NAACL'21): Concept-Fact Hypergraph, Dense fact embeddings