Motivations, Goal and Contributions

- **Time** is an important dimension for a knowledge base. Facts are dynamic in nature, new facts arise while some others cease to be true or change with time (e.g., fact: "Ronald Reagan is president of the United States" was true from 1981 to 1989).

- **Goal**: Temporally scope every fact in a knowledge base automatically:
  - Utilize large number of documents
  - In a scalable way: few training data

- **Hypothesis**: Knowing the temporal scope of one fact can be used to infer the time scopes of other related facts.
- **Temporal Relationships (orderings) between facts** can be inferred from narrative orderings of their mentions in documents.

**Contributions**:
- Joint inference of temporal scopes is effective compared to temporally scopeing of each fact independently.
- Temporal orderings of relations can be inferred from narrative orderings of their mentions.
- Large-scale open-domain publicly available time-stamped datasets, such as Google Books Ngrams, can be effective for time scoping.
- Pose temporal scoping task in a macro-reading fashion, as a change detection in a time series of facts' features computed from large datasets.

**Collective Inference**

- **Local Classification**

- **Collective Inference**?

- **Facts in NELL KB**

- **Temporal Alignment among Facts** (e.g., "Al Gore's Vice Presidency was contained within Clinton's Presidency")

- **Estimate Facts Timeline by querying facts over time-stamped datasets** (e.g., Google Books Ngrams, Gigaword)

- **Collective inference for final scoping, exploiting various temporal constraints**

**Temporal Constraints Acquisition**

- **Proposed Algorithm**

  - **GraphOrder**: graph-based semi supervised learning algorithm to induce transitivity closure over soft orderings

**Proposed Algorithm**

- **GraphOrder** is an integral part of CoTS Collective Inference module.

- **Estimate Facts Timeline** by querying facts over time-stamped datasets. Details in the figure to the left represents the temporal graph (solid red edges) imposed over NELL KB's factual graph. Edges in the temporal graph represent constraints which are used by CoTS Collective Inference module.

**Challenges and Ongoing Works**

- **Count Sparsity**: Queries for facts from some relations (e.g., "defenseSecretary") result in sparse counts in Google Books and Gigaword corpora. Possible solutions include:
  - Incorporate evidence from other large time-stamped datasets (e.g., Google News Archive)
  - Incorporate evidence from non-time-stamped datasets

**Experiments**

**Benefits of Collective Inference**

**Results of Temporal Scoping Experiments**

**Proposed Algorithm**

- **Collective Inference** module.

- **Temporal Constraints**

- **Collective Inference**

- **Estimate Facts Timeline** by querying facts over time-stamped datasets. Details in the figure to the left represents the temporal graph (solid red edges) imposed over NELL KB's factual graph. Edges in the temporal graph represent constraints which are used by CoTS Collective Inference module.

- **Temporal Scoping Experiments**

- **Proposed Algorithm**

- **Collective Inference** module.

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- **Temporal Scoping Experiments**

- **Proposed Algorithm**

- **Collective Inference** module.

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- **Temporal Scoping Experiments**