NaturalLI: Natural Logic Inference for Common Sense Reasoning

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Motivation

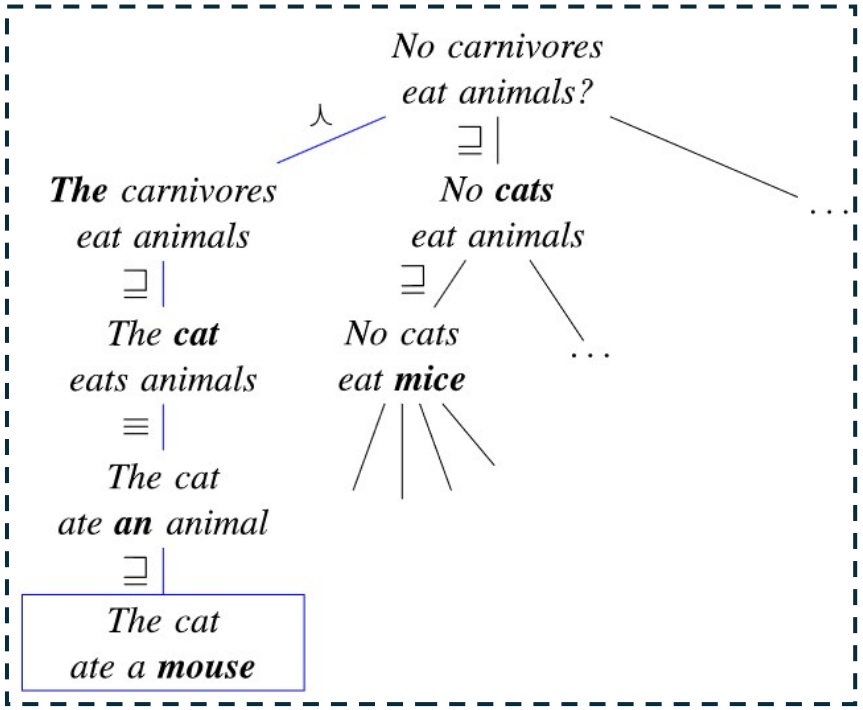
- **Problem:** AI systems often lack common-sense reasoning, which is essential for interpreting implicit information and enhancing accuracy in tasks across natural language processing, computer vision, and robotics. This issue limits AI's effectiveness in making inferences that align with human intuition.

- **Goal:** Develop a Natural Logic inference system capable of deriving common-sense knowledge by drawing inferences from a large database of established facts.

Background Work

- **Previous Work:** Prior Natural Logic systems focused on single premise inferences with formally valid inferences.
  - **Single-Premise Inferences:** Derived conclusions based on one statement at a time
  - **Formally Valid Inferences:** Ensures logical correctness. If the premise is true, the conclusion is true.
- **Proven Approaches:** Projects like Abstract Meaning Representation (AMR) and Open Information Extraction (OpenIE) have successfully collected large databases of natural language snippets.
  - **AMR:** Encodes sentence meaning as a graph, abstracting away syntax to represent similar semantics across different wordings.
  - **OpenIE:** Extracts structured information from unstructured text without predefined relations.
- **Comparison:** NaturalLI improves by handling large sets of premises, not requiring explicit alignment, and allowing imprecise inferences, which are conclusions or opinions formed based on data or information that is not exact or precise.

Method



- **Search-Based Approach:** Casts inference as a search problem by scanning a database of known facts to find premises that support a query. Uses text mutations to test inference validity.
- **Lexical Transitions:** Alters words/phrases with predefined templates (e.g., hypernymy, synonymy) to explore inferences, assigning costs to reflect confidence in each step.
- **Natural Logic:** Evaluates each transition's validity, enabling precise inference by following logical steps through language modifications.

Method

- **Advantages:** Handles unstructured text, scalable to large databases, and integrates confidence inferences.
- **Disadvantages:** Limited by the quality of the database(correctness & completeness of the facts) and potential search errors.
- **Limitations:** Lacks an understanding of grammatical relationships and can lead to inference errors.
- **Fitting Scenarios:** Suitable for broad-coverage database completion tasks, which involve predicting whether unseen facts should be included in a large database of known facts.

Experiment

- **Implementation:** Uses a large database of 270 million entries, with search paths corresponding to Natural Logic inference steps.
- **Proof:** Demonstrates ability to capture Natural Logic inferences and predict common sense facts.

Result:

System	P	R
Lookup	100.0	12.1
NaturalLI Only	88.8	40.1
NaturalLI + Lookup	90.6	49.1

- **Performance:** NaturalLI achieves 49% recall and 91% precision, effectively predicting common-sense facts beyond direct lookups(checks if the fact exists in the database).
- **Advantages & Disadvantages:** High precision and broad coverage, but recall is limited by alignment challenges.

Conclusion

- **Meaningfulness:** Shows the potential of Natural Logic for broad-coverage database completion.
- **Experiment Findings:** Validates the system's ability to infer common sense facts and handle large-scale inference tasks.

Applications on storytelling.

- **Dynamic Plot Generation:** Uses Natural Logic to infer plausible, logically consistent story developments and plot twists from narrative databases.
- **Realistic Character Behavior:** Applies common-sense reasoning to predict believable character actions and dialogue, enhancing immersion.
- **Interactive Decision Making:** Enables player choices to impact the story meaningfully, with Natural Logic ensuring coherent consequences.
- **Automated World Building:** Generates consistent, detailed settings by inferring environmental rules and facts from a knowledge database.