Different approaches in the study of symmetric and asymmetric linguistic relations

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Abstract: *This article studies several approaches in the study of symmetric and asymmetric linguistic relations. We analyzed differences between symmetric and asymmetric relations linguistically. Theories of outstanding scholars, such as Gleitman, Senghas, Flaherty, Coppola, Goldin-Meadow were analyzed in details.*

Key words: *symmetric relations, asymmetric relations, feature-based approach, context-based approach, symmetry in logic, empirical tradition, language interference.*

Introduction

Symmetry helps one make systematic inference about relations in the world and is a fundamental property of natural language (Gleitman, Senghas, Flaherty, Coppola, & Goldin-Meadow, 2019). A symmetrical predicate describes a reciprocal relation and collective participation between entities.

There are a number of approaches of the study of symmetric and asymmetric linguistic relations.

1. The feature-based approach. Gleitman and colleagues (1996) found that sentence interpretation heavily depends on its syntactic structure and the lexical-semantic properties of the predicate and entities involved. For example, any predicate can appear symmetrical in a non-directional sentence format (where the entities are placed on one side of the verb, e.g., *Anna and Gab kissed*). Gleitman and colleagues' work suggests that symmetric inference is grounded in linguistic features. However, their findings were based purely on empirical investigation, and no formal approach has been developed to model symmetric inference in language and evaluated comprehensively against data.

The feature-based approach is insufficient to capture all possible real-world relations between entities. As Gleitman et al.(1996) noted, context becomes relevant to determine degree of predicate symmetry such as in the following pair of sentences: *My sister met Meryl Streep* (judged asymmetric) and *John met Mark* (judged symmetric), which indicates that sentences similar in lexical and syntactic features do not always yield the same symmetry judgment.

2. The context-based approach. Focusing on the symmetric predicate similar instead of verb predicates in their generality, Tversky and Gati (1978) elaborated further on the role of context. First they examined the nature of entities. They deliberately chose entities that are conceptually close in prominence (e.g. *Austria, West Germany*) or much different (e.g. *England, Jordan*), and found that symmetric inference can depend on one's world knowledge. In a related experiment, they showed that inference involving the predicate similar can be manipulated with contextual information. For example, Hungary was judged to be more similar to Austria than Sweden or Norway, but Sweden was judged to be more similar to Austria than Soviet aligned Hungary or Soviet-aligned Poland. This approach highlights the need to formalize a contextual approach to symmetry and evaluate how it interacts and fairs with the feature approach.

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Our view is that both linguistic features and contextual knowledge matter in symmetry judgment, and integrating the two approaches described should facilitate systematic inference (Fodor,1987) in models of natural language processing (NLP). We develop a naturalistic sentence dataset for symmetry inference of literature-informed verbs spanning symmetry-asymmetry that is underrepresented in existing natural language inference datasets such as SNLI (Bowman et al.,2015).

We show that whereas a contextualized language model helps operationalize a context-based approach to symmetry inference, it is critically lacking in learning linguistic features pertaining to symmetry. We propose a hybrid transfer learning model that integrates linguistic features with context and demonstrate its efficacy in improving systematic inference of contextual language models.

3. Symmetry in logic vs. empirical tradition. In logic, symmetry and reciprocity (Siloni,2012; Winter,2018) are treated differently, but the difference is often overlooked in empirical tasks. Symmetrical predicates describe a collective event encompassing all entities involved, while reciprocity relates propositions (Gleitman et al.,2019). In other words, symmetry describes one event and reciprocity describes multiple events occurring with the same action and the same entities but only with roles reversed. To exemplify the difference, take the following sentences: John and Mary hug and John and Mary hug each other. The first sentence is symmetric and reciprocal, as hugging here is one event with simultaneous reciprocation. The second sentence, however, arguably describes two separate events occurring sequentially: hug (John, Mary) and then hug (Mary, John) (Winter,2018). The difference between symmetry and reciprocity is not syntactically obvious, which is why humans tend to treat the two concepts as the same in sentence-only tasks (Gleitman et al.,1996). Empirical studies have since used visual stimuli to help participant's separate symmetry and reciprocity (Kruitwagen et al.,2017; Majid et al.,2011). Given these findings, we do not expect human judgment to differentiate symmetry and reciprocity problem from sentence-only stimuli. However, it is instructive to explore how NLP models, particularly contextualized language models such as BERT (Devlin et al.,2018), would fare in these cases.

4. Symmetry and systematicity in natural language interference. Psycholinguistic research suggests that conceiving symmetry relations relies on essential human capabilities of language understanding. However, few studies have modelled symmetry inference computationally or tested models against empirical data. Symmetry inference can be treated as a special case of recognizing textual entailment (RTE): the pair of input sentences for symmetry problems are typically identical, except that the entities (e.g., subject and object) associated with the target predicate are permuted. Existing studies in semantic inference have constructed NLP systems to predict entailment directionality between simple expressions (Bhagat et al.,2007). However, their methods often rely on human-annotated features and fail on more complex examples where contextual dependency is essential for entailment recognition. Deep contextualized language models have since been shown to capture rich contextual information in various natural language inference (NLI) tasks, which is a promising starting point for modelling symmetry in natural context (Peters et al., 2018). However, the interpretability and robustness of these large-scale pre-trained models are yet to be evaluated on symmetry inference. In a series of case studies, Goodwin and colleagues (2020) demonstrated that despite the high overall performance, state-of-the-art NLI systems consistently failed to capture the contribution of certain classes of words or regularities in semantic representation. The inability to generalize systematically is also observed when training sequence-to-sequence neural models to understand instructions with compositional semantic structures (Lake and Baroni,2018). Our methodological framework for symmetry inference is intimately related to systematicity in NLI. A systematic learner should be able to infer for instance that *I kissed her* has a higher degree of asymmetry than *We kissed each other*. In a comprehensive set of analyses, we demonstrate that both contextual and linguistic cues are essential for accurate inference about symmetry, and a joint approach helps to improve inference in contextualized language models.

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5. Feature model. For each input sentence, the feature-based encoder first performs dependency parsing, and then extracts a sequence of syntactically-induced, categorical feature variables indicating the existence of certain linguistic patterns. We choose features that were 1) shown empirically to be associated with sentence level symmetry according to psycholinguistic literature; and 2) obtainable via an automatic feature extraction pipeline. Following classic empirical studies of symmetry (Gleitman et al.,1996), our model will infer symmetry from pre-defined linguistic features and a small amount of contextual information from these features (e.g., animacy).

6. Seed verbs. We focused on verbs because they are the most extensively studied word class in symmetry and have many established features. We worked with 40 common verbs from the literature, divided equally into symmetric and asymmetric categories. Table1shows the list of verbs. 22 of these verbs are taken from Gleitman et al. (1996)'s original experiments and have thus been previously categorized. The remaining verbs are taken from their reciprocal implication in the Collins English dictionary (1994) and in related literature (Winter, 2018; Siloni, 2012). The selected verbs represent the broad spectrum of symmetry-asymmetry. We show that certain linguistic cues, such as animacy, are predictive of symmetry and can be easily recognized by humans. To better probe whether contextualized models become more sensitive to such systematic variation after learning, we perform a focused analysis on a subset of SIS sentences controlling for these factors.

Conclusion

We present to our knowledge the first formal framework for modelling sentence-level predicate symmetry and demonstrate that automated inference of verb symmetry is possible in natural context. Contributing the symmetry inference sentence dataset, we show how existing approaches to symmetry, based on linguistic features and contextualization, are by themselves insufficient to explain sentence level symmetry judgment, but a hybrid approach improves systematic symmetry inference in state of-the-art language models. Future work may explore symmetry in other word classes (e.g., nouns and adjectives) and languages other than English.

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