COMP5450M COURSEWORK 2B

By: Ryan Chung(sc19rc), Yeuk Fong(sc19yhcf), Mark Muinde (sc19msmm)

Introduction

"A Winograd schema is a pair of sentences that differ only in one or two words that contain a referential ambiguity that is resolved in opposite directions in the two sentences." (Levesque et al., 2012). Each schema is meant to challenge the reasoning capacities of intelligent systems. The two differing words in the sentences are defined as the 'special word', and the 'alternate word'. This essay will refer to these words as 'operating words'. Referential ambiguity arises because the operating word in use determines which individual is the subject of the sentence. In this essay, the subject of the sentence will be referred to as the 'referent'.

The schema chosen in this essay is schema number 90 of Ernest Davis' original collection of 150 Winograd schemas. The schema reads as follows:

> *In July, Kamtchatka declared war on Yakutsk. Since Yakutsk's army was much better equipped and ten times larger, they were [victorious/defeated] within weeks. Who was [victorious/defeated] ?*
> ***Answers:*** *Yakutsk/Kamchatka.*
> ***Comment:*** *Winograd schema in the broad sense, since with "defeated" there is no plural to serve as referent of "they".*

This schema has been chosen as it can be used to display the power and extensive possibilities of effectively using first-order logic to solve Winograd schemas.

Informal Analysis

The schema refers to two people who have declared war on each other. One of the people wins because his army was larger and better equipped; and consequently the other person loses. This schema is very easy for a human to disambiguate, but what about an intelligent agent?

The operating words here are 'victorious', and it's alternate 'defeated'. If victorious is used in the sentence, then the referent is obviously Yakutsk, and if the word is defeated, then the referent is Kamchatka. 'They' is used as the pronoun because it is the individual's army that is engaging in the war, not the individual. Perhaps the referents should then be changed to 'Yakutsk's army' and 'Kamchatka's army'. However, that would make no inferential difference as the answers (the individuals) are the possessors/commanders of their respective armies. Therefore the answers, though not suitable for the pronoun in the traditional English sense, will serve their purpose for the schema as the referents.

An intelligent agent able to use reasoning to disambiguate the schema via the operating words can determine which individual is the referent. To do this, the intelligent agent would need the facts of the

statement. These facts are the names of the individuals, which individual has the better-equipped and larger army (the winning army), and the operating words. Fortunately, with the right knowledge representation and reasoning method and representation, the only facts an intelligent agent will need are the names of the individuals and the operating words. This is discussed in the formal analysis.

Formalisation Using KRR Methods

To solve this Winograd schema, we propose to use first-order logic to code a theorem. This theorem can then be tested with an automatic theorem prover to allow an intelligent agent to determine the referent. This can be accomplished using the Prover9 theorem prover as formally defined below:

	Statement	**Representation**
A1	" 'victorious' is an operating word."	Word(victorious).
A2	" 'defeated' is an operating word."	Word(defeated).
A3	"Kamchatka is a referent."	Referent(Kamchatka).
A4	"Yakutsk is a referent."	Referent (Yakutsk).
A5	"If the operating word is 'victorious', then Yakutsk is the referent."	Word (victorious) ←→ Referent(yakutsk).
A6	"If the operating word is 'defeated', then Kamchatka is the referent."	Word (defeated) ←→ Referent(kamchatka).
GOAL	"The operating word can be either 'victorious' or 'defeated'."	Word (victorious) | Word (defeated).

Properties: `Referent`, `Word`.
These indicate the properties of being the referent and the operating word respectively.

Names: `yakutsk`, `kamchatka`,`victorious`, `defeated`.
The first two names are the individuals in the schema. The last two names are the schema's operating words.

Limitations

The proposed theorem's representation is sufficient to support a solution of the schema's problem by an automatic theorem prover. To prove this, a Prover9 file was created and tested. A screenshot of the same, and evidence of the theorem being proved when ran, are provided in Appendix A.
Nevertheless, this solution is dependent on the facts of the schema not changing. If the names of the individuals or the commander of the winning army was to change, the theorem would require refactoring.

References

1. Levesque, H., Davis, E. and Morgenstern, L. (2012). *The Winograd Schema Challenge*, *aaai.org*. Association for the Advancement of Artificial Intelligence. Available at: https://www.aaai.org/ocs/index.php/KR/KR12/paper/view/4492/4924 (Accessed: December 2, 2022).

Appendix A: Prover9 Theorem Validity Evidence

```
%% A1: "'victorious' is an operating word."

        Word (victorious).

%% A2: "'defeated' is an operating word."

        Word (defeated).

%% A3: "Kamchatka is a referent."

        Referent(kamchatka).

%% A4: "Yakutsk is a referent."

        Referent(yakutsk).

%% A5: "If the operating word is 'victorious', then Yakutsk is the referent."

        Word (victorious) <-> Referent(yakutsk).

%% A6: "If the operating word is 'defeated', then Kamchatka is the referent."

        Word (defeated) <-> Referent(kamchatka).


end_of_list.

formulas(goals).

%% GOAL: "The operating word can be either 'victorious' or 'defeated'."

          Word(victorious) | Word(defeated).

end_of_list.
```

```
(base) markmuinde@MacBook-Pro-2 cwk2 % cp 90.p9 90.in

(base) markmuinde@MacBook-Pro-2 cwk2 % prover9 -f 90.in>90.out

-------- Proof 1 --------

THEOREM PROVED

------ process 63470 exit (max_proofs) ------
```