Knowledge Representation and Reasoning MSc

Assignment 3

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KRR Challenges and Potential

1. Introduction

(*848 words*)

The methodology of Knowledge Representation And Reasoning(KRR) is a major branch of Artificial Intelligent(AI) research, and it employs symbolic representation of information together with logic inference procedures as a tool for solving common-sense reasoning problems. More informally, it is part of AI that is concerned with thinking, and how thinking contributes to intelligent behaviour(Brachman, 2004). Although KRR as a mean gives some ideas and techniques are used in a wide variety of AI systems, it is facing some challenges when using it to solve the common-sense that is expressed in natural languages. Normally, it is necessary to need to a method or task to evaluate the performance of common-sense reasoning in automatic systems using the KRR techniques.

1.1 Winograd Schema Challenge

The Winograd Schema Challenge(WSC), introduced by Hector Levesque(Levesque et al., 2012), is an alternative to the Turing test (Turing,1950) that provide a test of AI system's ability to solve the common-sense reasoning. WSC is made of special types of pronoun resolution problems. It includes more than 100 instances and every instance called Winograd Schema(WS) (Winograd, 1972). A WS is a pair of sentences that differ in only one or two words and that contains an ambiguity that is resolved in opposite ways in the two sentences. Specifically, a WC sentence is a simple reading comprehension test requiring people to answer a question which has one pronoun, and it also provides two answers with the different referent in the sentence. These examples can be found on the webpage (https://cs.nyu.edu/faculty/davise/papers/WinogradSchemas/WS.html). A well-known WC example was presented by Terry Winograd(1972):

<u>The city councilmen</u> refused <u>the demonstrators</u> a permit because they [feared/advocated] violence. Who [feared/advocated] violence?

Answers*:* *the city councilmen / the demonstrators.*

If the sentence is '... a permit because they feared violence', then the pronoun 'they' refers to the city councilmen and the correct answer is the city councilmen; If the sentence turns into '... a permit because they feared violence', then the correct answer is the demonstrators. For such problem, Human reader can easily to answer this question, but it is difficult for a computer.

According to Levesque et al. (2012) suggestions, these WSs should have three restrictions. First, human reader is able to disambiguate these questions easily. Second, these questions should not be solved by simple techniques such as selectional restrictions. Third, they should be Google-proof. Besides, A formal description of a WC question should have four features:

1. Two parties (such as males, females, groups of people or objects) are mentioned in a sentence by noun phrases.
2. A pronoun or possessive adjective may refer to either of the above parties.
3. The question involves determining the referent of the pronoun or possessive adjective.
4. There is a special word in the sentence or the question. If the special word replaced by an alternate word, then the sentence still has a complete sense and the question will have a different answer (Levesque et al., 2012).

1.2 Choice of Plausible Alternatives

Another popular reasoning evaluation tool called the Choice of Plausible Alternatives (COPA) to test common-sense reasoning in automatic systems was offered by Roemmele et al. (2011). The COPA set includes 1000 questions. These examples can be found on the webpage (https://people.ict.usc.edu/gordon/public_html/copa.html). Each question has a premise and two candidates causes or effects and it have should have a reasonable choice in these alternatives, as in the following example:

Premise: *The man lost his balance on the ladder. What happened as a result?*
Alternative 1: *He fell off the ladder.*
Alternative 2: *He climbed up the ladder.*
The alternatives are all conceivable, human readers are able to select a reasonable alternative in two alternatives.

The COPA evaluation tool has a similar style with the Recognizing Textual Entailment challenge (Dagan et al., 2006), but there have some differences between them. The COPA focus on the cause implication rather than entailment and it concerns the defeasible inferences that can be drawn from the interpretation of a sentence (Gordon et al., 2012).

1.3 Why it is significant for Artificial Intelligence

The WSC was proposed in the spirit of the Turing test and it plays a role as an extension and inheritance of the Turing test. The importance of the Truing test in AI research has long been recognized. Similarly, the WSC research is very meaningful to the development of AI. The COPA have the same function with WSC in common-sense reasoning, so the studying of COPA is also significant for AI.

However, there is no good performance to solve WSC and COPA problem so far. It is difficult for a computer to solve these questions. Using KRR techniques to solve these questions, the highest accuracy is 72.7%, up to now, reported by Vid Kocijan et al. (2019). 72.7% is not good accuracy and well below the expected accuracy, since 50% accuracy can be get based on the random choice. In terms of COPA, 75.4% accuracy on the COPA test set achieved by Li et al. (2019), which is also not a high accuracy. Therefore, it is clear that the reason why the computer solves WSC or COPA problems is difficult. If Any implements using KRR techniques achieves high accuracy, it will have a breakthrough on common-sense reasoning.

2. Specific KRR problem examples

Various approaches were introduced to solve the WSC problems. In this section, a classical method called First-Order Logic (FOL) (Mendelson, 2009) reasoning will be used to solve a specific WSC example.

2.1 First-Order Logic Reasoning to solve the WSC

According to Bova and Rovatsos, a framework was reported to solve WSC. The framework consists of three sub-tasks:

1. The sentence in the schema need to analysed by some useful techniques and expressed a form able to copy with using FOL.

2. The output of the previous step is the input of this task. In addition to this, It is necessary to add an external knowledge base for relevant facts, concepts along with the sentence. Then, all information contained in the contest translated into the logic expression of FOL.

3. The output of the previous step is used as the input of an inference system, such as Prover9. it is an automatic theorem prove (ATP). For each of the two twin WSC sentences, if ATP is able to prove the correct answer of them by reasoning, WSC can be solved by this method.

2.2 Example: schema 43 & 44

According to the rules, trying to solve schema number 43 and 44.

Schema 43:

Sentence: *I poured water from the bottle into the cup until it was empty.*

Pronoun: *it*

Candidates: *The bottle / the cup*

Correct answer: *the bottle*

Schema 44:

Sentence: *I poured water from the bottle into the cup until it was full.*

Pronoun: *it*

Candidates: *The bottle / the cup*

Correct answer: *the cup*

Firstly, translate the sentences to FOL expression and it will get two candidates: the bottle and the cup. For each of them can be express a constant. So, each of them can be expressed in a predicate.

1. bottle(B).

2. cup(C).

Since the two candidates are distinct objects, a candidate predicate does not apply to other's constant. Therefore, it is necessary to add two new assumptions to the list of assumptions.

3. ¬(bottle(C))

4. ¬(cup(B))

Then, an express represents either the target pronoun is equal to the first candidate and not to the second, or the way around.

5. (it = B ∧ ¬(it = C)) ∨ (it = C ∧ ¬(it = B)).

Then, for "it was empty" or "it was full", each of them can express in a predicate (ignoring the tense).

6. beEmpty(it)

7. beFull(it)

Similarly, a disjunctive expression in which the constant of the target pronoun is substituted by one of the candidates should add the list of assumptions.

8. (beEmpty(B) ∧ ¬beEmpty(C)) ∨ (beFull(C) ∧ ¬beFull(B))

The next step needs to deal with relations among clause in the sentence. ignoring the tense and using a relation expresses the 'poured water from the bottle into the cup'

9. pourWaterInto(B, C).

In this way, the FOL conversion for this sentence is complete. Next, we need to supplement the background, facts, rules and truths of the sentence. Base on the 1-9 predicts, we can add some new commonsense facts:

10. beEmpty(it) → pourWaterInto(B, C).

11. ∀x ∀y [bottle(x) ∧ cup(y) ∧ pourWaterInto(x, y) → beEmpty(x)].

12. ∀x ∀y [bottle(x) ∧ cup(y) ∧ pourWaterInto(x, y) → beFull(y)].

Finally, two goals that have to provided by ATP is the candidates refer to the pronoun.

it = B. or it = C.

All above the expressions express in FOL. They can easily convert into Prover9 languages. By introducing some constants (B, C), predicates (bottle, cup, beEmpty, beFull), relations (pourWaterInto), each of them translates into Prover9 expressions.

1. bottle(B).

2. cup(C).

3. -bottle(C).

4. -cup(B).

5. (it = B & -(it = C)) | (it=C & -(it=B)).

6. beEmpty(it).

7. beFull(it).

8. beEmpty(B) & -(beEmpty(C)) | beFull(C) & -(beFull(B)).

9. pourWaterInto(B, C).

10. beEmpty(it) -> pourWaterInto(B, C).

11. all x all y (bottle(x) & cup(y) & pourWaterInto(x, y) -> beEmpty(x)).

12. all x all y (bottle(x) & cup(y) & pourWaterInto(x, y) -> beFull(y)).

The goals need to proved by Prover9, following as:

it = B. or it = C.

3. Conclusion

In conclusion, I would not believe that KRR techniques are likely to be able to solve the reasoning challenge problems (such as WSC, COPA) with high accuracy. Although some approaches involving the KRR techniques have reported with an accuracy of more than 50%, it would not meet the result expected. For a simple schema of WSC, we need to firstly analysis the sentence by some natural language processing tools and a grammar parse tree of a schema is necessary. Then, we need to supplement the knowledge base. After that, we also need to translate the other expression expressing in symbols and rules of the logic reasoning system. Finally, we need to ATP prove the result. In these steps, it is difficult to translate the natural language into logic expression and a schema itself contains limited information, so it is difficult for computer to solve the problem.

However, from a system-design point of view, one of the advantages of using a knowledge-based approach or system solve the WSC problem is that approach has the ability to be told facts about its sentence. For example, a sentence consists of some facts and these facts can be express in logic symbols easily. We can also change or supplement some facts in systems to adjust the goal we want to prove. The other advantage is that we can create a model to store knowledge in an explicit way. Since the KRR approach mainly concerns the reasoning and how to represent the problem, the knowledge of the model is relevant to the problem.

On the other hand, sometimes, a simple schema can be solved by KRR approach easily but when using this approach deal with a complex schema, it will turn into a complicate task. One of the difficulties is there is no good method to analysis the sentence and translate the sentence into FOL expressions automatically. If the FOL method depends on the manual operation to translate the sentence and add the background knowledge, it will be an inefficient method. Besides, it is difficult for human to supplement the knowledge to the schema because there is no standard method tell us how to supplement background knowledge or how much background knowledge need to supplement, which will affect the complexity of the design of a reasoning system.

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