Optimization of an abductive reasoner for description logics

Master thesis

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FMFI, 2018

Aims

- Descripton logics
  - $\mathcal{ALC}$, $\mathcal{EL}$++
  - DL Tableau algorithm
- Abduction
  - ABox abduction
  - Minimal Hitting Set algorithm
- Reasoning
  - ELK, JFact, Hermit, Pellet
- Implementation
  - Reiter's algorithm with optimizations
  - adjusted MergeXPlain algorithm
- Evaluation of results

Description logics

- Family of knowledge representation languages
- Every description logic has different expressivity
- Each type of expressivity supports different constructors
- We will use $\mathcal{ALC}$ and $\mathcal{EL}$++ DL

- $\mathcal{ALC}$ DL is shaped by 3 mutually disjoint sets:

$$N_I = \{a, b, c, ...\}$$

$$N_C = \{A, B, C, ...\}$$

$$N_R = \{R_1, R_2, R_3, ...\}$$

- Individual, concept (atomic or complex)
- $\mathcal{ALC}$ DL consists of the following constructors:

$$\neg, \sqcup, \sqcap, \forall, \exists$$

DL conceptualization: Everybody who is sick, is not happy.

$$Sick \sqsubseteq \neg Happy \text{ (axiom)}$$

- Ontology describes relationships between entities in a specific area
- Knowledge base $\mathcal{KB} = (\mathcal{T}, \mathcal{A})$
- $\mathcal{T}$ stands for TBox, $\mathcal{A}$ stands for ABox
- TBox contains axioms that model ontology
- ABox contains assertion axioms

$$\mathcal{KB} = \left\{ \begin{array}{l} \mathit{Profesor} \sqcup \mathit{Scientist} \sqsubseteq \mathit{Academician} \\ \mathit{AssocProfesor} \sqsubseteq \mathit{Professor} \\ \mathit{jack} : \mathit{Academician} \end{array} \right\}$$

Reasoning

- Reasoning problems: consistency, satisfiability, inference
- Algorithm: DL Tableau algorithm
- Aims: finding model, classification
- Reasoners we work with: ELK, JFact, Hermit, Pellet

Abduction

- Knowledge base and observation is known
- Search for explanations

$$\mathcal{KB} = \left\{ \begin{array}{l} \mathit{Profesor} \sqcup \mathit{Scientist} \sqsubseteq \mathit{Academician} \\ \mathit{AssocProfesor} \sqsubseteq \mathit{Professor} \end{array} \right\}$$

$$\mathcal{O} = \{\mathit{jack} : \mathit{Academician}\}$$

- We use adjusted minimal HS algorithm to find minimal explanations
- Algorithm finds this explanation:

$$\mathcal{E}_1 = \{\mathit{jack} : \mathit{Professor}\}$$

$$\mathcal{E}_2 = \{\mathit{jack} : \mathit{Scientist}\}$$

$$\mathcal{E}_3 = \{\mathit{jack} : \mathit{AssocProfessor}\}$$

Adjusted Reiter's algorithm: Minimal Hitting Set

Algorithm 1 Adjusted Minimal Hitting Set algorithm

Require: $Ontology$, $observation\ \mathcal{O}$

$root \leftarrow negationOfModel$

$queue \leftarrow queue \cup root$

while $queue.isNotEmpty()$ **do**

  $node \leftarrow queue.pop()$

  for (Node child : node.children) **do**

    $consistent \leftarrow isConsistent(node)$; $relevant \leftarrow isRelevant(node)$

    $explanation \leftarrow isExplanation(node)$; $minimal \leftarrow isMinimal(node)$

    if (`explanation`) **then**

      $explanations \leftarrow explanations \cup node.label$

    else

      $queue \leftarrow queue \cup node$

    end if

  end for

end while

Adjusted Reiter's algorithm: Minimal Hitting Set

- Implementation with more reasoners (ELK/JFact/Hermit/Pellet)
- Elk should be quicker thanks to lower expressivity
- Optimizations:
  - Observation can not be an explanation
  - Explanation that is not minimal does not even have to be considered

Progress

- Implementation of Reiter's algorithm with optimizations for simple concepts:
  - Works for observation given as simple concept yet
  - Tested on 2 ontologies with correct results
- Started implementation of MergeXPlain algorithm for simple concepts:
  - Designed for observation given as simple concept yet

What is next?

- Modify implementation of Reiter's algorithm with optimizations:
  - To accept complex concept as observation
  - To accept more complex concepts as observation
  - Add more optimizations
- Modify implementation of MergeXPlain algorithm:
  - To process correctly observation given as simple concept
  - To accept complex concepts and possibly more complex concepts as observation
- Evaluation of results (ELK/JFact/Hermit/Pellet)

References

Articles

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Thank you for your attention