Attempto Controlled English for Knowledge Representation

Norbert E. Fuchs, Kaarel Kaljurand, Tobias Kuhn

Department of Informatics & Institute of Computational Linguistics
University of Zurich

{fuchs, kalju, tkuhn}@ifi.uzh.ch
http://attempto.ifi.uzh.ch/site/

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Overview

- Languages for Knowledge Representation
- Attempto Controlled English (ACE)
- Language ACE
- Translating ACE into First-Order Logic
- Attempto Tools
- Typical Applications of ACE
- Hands-On Training

Problem Knowledge Representation

- How should one represent the biological fact that every protein has a terminus?
- questions to be considered
  - Who is the author of the representation?
  - For which audience?
  - Using which representation, which language?
  - Informal or formal representation?
  - Representation processable by computer?

Some Solutions

- problem: represent the biological fact that every protein has a terminus
- solutions: example representations

first-order logic	$\forall X(protein(X) \rightarrow \exists Y(terminus(Y) \wedge has(X,Y)))$
DL	$Protein \sqsubseteq \exists has.Terminus$
OWL (RDF/XML)	<owl:Class rdf:ID="Protein"> <rdfs:subClassOf> <owl:Restriction> <owl:onProperty rdf:resource="#has"/> <owl:someValuesFrom rdf:resource="#Terminus"/> </owl:Restriction> </rdfs:subClassOf> </owl:Class>
UML	
ACE	Every protein has a terminus.

Languages for Knowledge Representation

- formal languages
  - + well defined-syntax, unambiguous semantics
  - + support automated reasoning
  - – conceptual distance to application domain
  - – incomprehensibility, acceptance problems
- natural language
  - + user-friendly: easy to use and understand
  - + no extra learning effort
  - + high expressiveness, close to application domain
  - – ambiguity, vagueness, incompleteness, inconsistency

Attempto Controlled English (ACE)

- Attempto Controlled English combines pros of formal and natural languages
- ACE is a *controlled* natural language
  - precisely defined, tractable subset of full English
  - automatic, unambiguous translation into first-order logic
- ACE is human *and* machine understandable
  - ACE seems completely natural, but is a formal language
  - ACE is a first-order logic language with an English syntax
- ACE *combines* natural language with formal methods
  - easier to learn and to use than visibly formal languages
  - automated reasoning with ACE via existing tools

An ACE Appetiser
(Actually Quite a Mouthful of ACE)

...

Every customer has at least two cards and their associated codes. If a customer C approaches an automatic teller and she inserts her own card that is valid carefully into the slot and types the correct code of the card then the automatic teller accepts the card and displays "Card accepted" and C is satisfied. No card that does not have a correct code is accepted. It is false that a customer's card is valid, and is expired or is cancelled. If there is someone X and it is not provable that X is a criminal then the bank can safely assume that X is trustworthy.

...

Important Notice

- The language ACE and the ACE parser do not contain any a priori knowledge of application domains or of formal methods. Users must explicitly define all domain knowledge – for instance definitions, constraints, ontologies – as ACE texts.

- Words occurring in ACE texts are processed by the ACE parser as uninterpreted syntactic elements, i.e. any meaning of these words is solely added by the human writer or reader.

The Language ACE

- like every language, ACE has
  - vocabulary/morphology
  - syntax
  - semantics
  - pragmatics
- ... and one must learn it (but wait until later)
- if you know English then you already know most of ACE
- thus let's see how ACE differs from English

English and ACE

- English is both syntactically and semantically more powerful than ACE
- English is used in human-human communication while ACE is also meant to be used in human-computer communication…
- ... which means that ACE is really a formal language (like various logics)
- ACE simply resembles English syntactically and semantically

English and ACE

- like English, ACE allows syntactically different sentences to express the same meaning (i.e. there is a lot of synonymy)
- unlike English, each ACE text is interpreted in just one way
  - ACE is not ambiguous
  - an ACE text read as an English text can have other meanings

Learning ACE

- vocabulary/morphology
  - predefined *function words* (articles, conjunctions, …)
  - predefined *fixed phrases* ('there is a ...', 'it is false that ...')
  - user-defined *content words* (nouns, verbs, adjectives, adverbs) and their forms
- construction rules (syntax)
  - define admissible sentence structures
  - avoid ambiguous or imprecise constructions
- interpretation rules (semantics)
  - control logical analysis of admissible sentences
  - resolve remaining ambiguities
- style guide, tools (pragmatics)

Vocabulary

- content words
  - dog, cat, like, red, manually, …
- content words can change morphologically
  - a man, 2 men
  - likes, does not like, is liked by
  - good, better than, best
- function words
  - if, then, who, 42, and, or, not, ...

ACE Content Words

- ACE content words are *nouns*, *verbs*, *adjectives* and *adverbs*
- set of ACE content words is infinitely large and dynamic
- all English content words are also ACE content words
  - e.g. podcast, groovy
- multiword units are always hyphenated
  - e.g. fill-in
  - e.g. persona-non-grata
  - e.g. switch-off

Semantics of Content Words

- no predefined lexical semantics
  - e.g. *bank* is underspecified
  - e.g. *narcissist* is just a noun with no relation to the verb *like*
  - e.g. *unacceptable* is just an adjective with no encoded negation
- users can of course add semantics by using ACE sentences
  - Every narcissist likes himself.
  - Everything that is not acceptable is unacceptable.
- this information is not used during parsing, but only by an eventual reasoning tool

ACE Nouns

- common nouns
  - countable: man, woman, cat
  - mass: water, money
- proper names
  - John, Mary
- countable nouns and proper names distinguish singular and plural
- all nouns carry gender information (masculine, feminine, neuter)
- measurement nouns
  - basic SI units: m, kg, ...

ACE Verbs

- subcategorisation (intransitive, transitive, ditransitive)
  - sit, like, give
- two forms of ditransitives
  - give something to somebody, give somebody something
- singular and plural forms
  - likes, like
- past participle forms for transitive and ditransitive verbs
  - liked
  - given
- phrasal and prepositional verbs
  - drop-out, fill-in

ACE Adjectives and Adverbs

- positive, comparative and superlative adjectives
  - tall, taller than somebody, tallest
- adjectives can have a PP-object
  - fond-of something
- positive, comparative and superlative adverbs
  - quickly, more quickly, most quickly

Content Words: Implementation

- full-form common lexicon of close to 100'000 entries
- users can import domain-specific lexicons of content words that can override entries of the common lexicon
- users can temporarily introduce missing content words by prefixing them with their respective word class
  - *A a:trusted man a:deliberately v:backs-up the n:web-page of the n:pizza-delivery-service.*
- ACE parser can in many cases guess the correct word class of an unknown content word on the basis of its context

ACE Function Words

- predefined function words
  - determiners, quantifiers, prepositions, coordinators, negation words, pronouns, query words, copula *be,* Saxon genitive marker '*s*
  - numbers
- predefined fixed phrases
  - *there is/are … such that*
  - *it is false that …*
- set of function words is limited and unchanging
- not all English function words are in ACE
  - e.g. hence, whom

Construction Rules: Noun Phrases

- singular countable noun phrases: *a/the/1 card*, *no card*, *every/each card*, *not every/each card, for every/each card*
- plural countable noun phrases: *the cards*, *some cards*, *3 cards*
- mass noun phrases: *some water*, *no water*, *all water*, *not all water*, *for all water*
- proper names: *John*, *Mr-Miller*
- (non-) reflexive (possessive) pronouns: *he/she/it/they, him/her/it/them, himself/herself/itself/themselves, his/her/its/their, his/her/its/their own*
- indefinite pronouns: *someone*, *somebody*, *something*, *no one*, *nobody*, *nothing*, (*not*) *everyone*, (*not*) *everybody*, (*not*) *everything*
- generalised quantifiers: *at least 2 cards*, *at most two cards*, *more than 10 cards*, *less than three cards*
- measurement noun phrases: *2 kg of apples, 3 cubicmeter of water*

Construction Rules: Complete and Unmodifyable Noun Phrases

- some elements of ACE are considered complete noun phrases that cannot be modified by, for instance, adjectives or relative phrases
- numbers
  - *2*, *three*, *3.14*, *-3*
- strings
  - "*Go!*"
- sets
  - *{John, Mary}*
- lists
  - *[1, 2, 3]*

Construction Rules: Complete and Unmodifyable Noun Phrases

- variables
  - *X*, *X13*
  - variables are introduced
    - in apposition to noun phrases *a man X*
    - as "bare" variables *X* (= *something X*)
- expressions
  - *3*(X+2)*
  - "*abc*" & "*123*"
  - expressions are not evaluated by the parser

Construction Rules: Plural Noun Phrases

- ACE plural noun phrases have a collective or a distributive reading
- collective reading is the default
  A clerk enters 2 cards.
- distributive reading is indicated by *each of*
  A clerk enters each of 2 cards.
- NP conjunction gives a plural object
  (each of) a customer and a clerk

Construction Rules: Modifying Noun Phrases

- adjective: *a rich customer, some cold water*
- adjective conjunction: *a rich and famous customer*
- *of*-prepositional phrase: *a customer of John*
- Saxon genitive: *John's customer*
- possessive pronoun: *his (own) card*
- variable as apposition: *a customer X*
  (NB: Variables introduced as appositions can be used anaphorically as noun phrases, e.g. *A customer X waits. X is tired*.)

Construction Rules : Relative Clauses

- relative clause: *a customer who knows John*
- relative clause (with inversion): *a customer who John knows*
- complex relative clauses
  - conjunction: *a customer who is rich and who is famous*
  - disjunction: *a customer who is rich or who is famous*
  - embedding: *a customer who sees a man who knows John*
  - embedding (with inversion): *a customer who a man who knows John sees*

Construction Rules: Verb Phrases

- intransitive (*wait*), transitive (*enter something*, *wait-for something*), and ditransitive verbs (*give something to somebody, give somebody something*)
- 3rd person singular/plural, present tense, active/passive
- modality (*can*, *must*)
- intentionality (*believe that*)
- prepositions of prepositional verbs and phrasal particles of phrasal verbs must be hyphenated to the verb (*wait-on*, *look-up*, *apply-for*)

Construction Rules: Verb Phrases

- copula *is*/*are* plus
  - noun phrase: *John is a rich customer*.
  - adjective: *John*'*s wealth is enormous*.
  - comparative adjective: *John is richer than Mary*.
  - transitive adjective: *John is interested-in Mary and fond-of Bill*.
  - prepositional phrase: *John is in his own office*.

Construction Rules: Modifying Verb Phrases

- adverbs follow the verb or – if present – its complements
  - *A customer waits patiently*.
  - *A customer inserts a card manually*.
- adverbs can also precede the verb
  - *A customer manually inserts a card*.
- adverbs can be conjoined (but not disjoined)
  - *A customer inserts a card carefully and manually*.
- prepositional phrases can be concatenated
  - *A customer inserts a card in the bank at a time T*.
- adverbs and prepositional phrases can be concatenated
  - *A customer inserts a card carefully into the slot*.
  - *A customer carefully inserts a card into the slot*.

Construction Rules: Complement vs Adjunct

- notice the difference between a prepositional/phrasal verb and a verb with a prepositional phrase

  A steward waits-on a table.

  vs.

  The food waits on the table.

  A student is interested-in a course.

  vs.

  A student is interested in a classroom.

Construction Rules: Verb Phrase Coordination

- VPs can be coordinated by *and* and *or*
- conjunction
  - *A screen flashes and blinks*.
- disjunction
  - *A screen flashes or blinks*.
- combinations of conjunctions and disjunctions follow standard binding order of conjunction and disjunction
  - *A screen {flashes and blinks} or is dark*.
- order can be overridden by commas
  - *A screen flashes, and {blinks or is dark}*.
- NB: The brackets { } are not part of ACE and are only used here to make the binding order explicit.

Construction Rules: ACE Texts

- ACE text is a sequence of anaphorically interrelated declarative sentences optionally followed by one interrogative sentence.
- declarative sentences
  - end with full stop
  - can be simple or composite
- interrogative sentences
  - end with a question mark
  - query the contents of ACE texts
- furthermore there are imperative sentences

Construction Rules: Simple Sentences

- simple sentences have the structure
  - subject + predicate + complements + adjuncts
- complements are the direct and indirect objects
- adjuncts are optional adverbs and prepositional phrases
- examples
  - *A customer waits*.
  - *A customer inserts a card*.
  - *A customer gives a card to a clerk*. (alternatively: *A customer gives a clerk a card*.)
  - *A customer inserts a card manually into a slot*.

Construction Rules: *there is* Sentences

- it is possible to create well-formed simple sentences without a verb by using the *there is/are* construct that introduces only an object
  - *There is a customer*.
- no adjuncts or complements are allowed (because there is no main verb)
  - **There is a customer in the bank*.
  - NB: The asterisk * means here that the sentence is syntactically incorrect.
- relative clauses are possible (because a noun is present)
  - *There is a customer who waits*.

Construction Rules: Formulas

- logical formulas constitute another form of simple sentences
  - 10 = 4 + 6.
  - 5 > 3.
  - X >= 13.4.
- formulas are not evaluated by the parser

Construction Rules: Composite Sentences

- composite sentences are recursively built from simpler sentences with the help of the predefined constructors
  - coordination
  - quantification
  - negation
  - subordination

- example
  - *If a customer inserts a card that is valid then the automatic teller accepts the card and displays a message.*

Construction Rules: Coordination

- sentences can be coordinated by *and* and *or*
- sentence conjunction
  - *The screen blinks and John waits*.
  - *3 < 4 and 3 =< 5*.
- sentence disjunction
  - *The screen blinks or John waits*.
  - *X < 4 or X >10*.
- overriding of standard binding order by commas
  - *The screen blinks or John waits, and Mary sleeps*.

Construction Rules: Quantification

- existential quantification
  - *There is a card. There is some water.*
  - *John enters a card. John drinks some water.*
- universal quantification
  - *John enters every card. Every card is valid.*
- global existential quantification
  - *There is a code that every clerk enters.*
  - or equivalently: *There is a code such that every clerk enters it.*
  - or equivalently: *There is a code that is entered by every clerk.*
- global universal quantification
  - *For every code a clerk enters it.*

Construction Rules: Negation

- negated existential quantifier
  - *John enters no code.*
- negated universal quantifier
  - *John enters not every code.*
- VP negation
  - *John does not enter a code.*
- negated copula
  - *Some water is not drinkable.*
- sentence negation
  - *It is false that a screen blinks.*
  - *It is false that a screen blinks and that the computer sleeps.*

Construction Rules: Subordination

- ACE knows several forms of subordination
  - relative phrases (we discussed them already when talking about noun phrase modification)
  - conditional sentences
  - sentence subordination
  - modality

Construction Rules: Conditional Sentences

- conditional sentences are built with the help of *if … then*
  - *If John enters a card then the automatic teller accepts it*.
- equivalence of universally quantified and conditional sentences

  Every customer enters a card.

  is equivalent to

  If there is a customer then the customer enters a card.

Construction Rules: Sentence Subordination

- negation
  - *It is false that a customer inserts a card*.

- negation as failure (to support translation of ACE into rules and into languages like Prolog)
  - *It is not provable that a customer inserts a card*.

- sentence as an object of a verb
  - *A clerk believes that a customer inserts a card*.

Construction Rules: Modality

- possibility
  - *A trusted customer can insert a card.*
  - *A trusted customer cannot insert a card.*
  - *It is possible that a trusted customer inserts a card.*
  - *It is not possible that a trusted customer inserts a card.*
- necessity
  - *A trusted customer must insert a card.*
  - *A trusted customer does not have to insert a card.*
  - *It is necessary that a trusted customer inserts a card.*
  - *It is not necessary that a trusted customer inserts a card.*

Construction Rules: Interrogative Sentences

- ACE allows two forms of interrogative sentence
  - yes/no queries
  - wh-queries
- yes/no queries
  - *Does John enter a card?*
  - *Is the card valid?*
- wh-queries
  - *Who enters what?*
  - *Which customer enters a card?*
  - *How does John enter a card?*

Ambiguity in English and in ACE

- English is a highly ambiguous language
- ambiguity can occur on several levels
  - syntax: *A man sees a girl with a telescope*. *John has a flat mate*.
  - scope: *Everybody loves somebody*.
  - lexical: *Mary sees a bank*.
- English relies heavily on context to resolve ambiguity
  - *A man sees a girl with a green dress*.
- ACE uses only structural information to resolve ambiguity
  - *A man {sees a girl with a telescope.}*
  - *A man {sees a girl with a green dress.}*
- ACE sentences are not ambiguous; however the same sentences can be ambiguous when read as full English

Constraining Ambiguity: Structural Ambiguity

- ACE employs three simple means to constrain the ubiquitous structural ambiguity of natural language
  - some ambiguous constructs are not part of ACE; unambiguous alternatives are available in their place
  - all remaining ambiguous constructs are interpreted deterministically on the basis of a small set of *interpretation rules*
  - users can accept the assigned interpretation, or they must rephrase the input to obtain another one
- here is an ...

Constraining Ambiguity: Structural Ambiguity

- ... example:
  - input 1: *A customer inserts a card that is valid and has a code.*
  - *paraphrase 1: A card B is valid. A customer A inserts the card B. The customer A has a code C.*
  - *input 2: A customer inserts a card that is valid and that has a code.*
  - *paraphrase 2: A card B is valid. A customer A inserts the card B. The card B has a code C.*

Interpretation Rules: Ambiguity

- prepositional phrases modify the verb not the noun
  - *A customer {enters a card with a code}.*
- relative clauses modify the immediately preceding noun
  - *A customer enters {a card that carries a code} and opens an account.*
- to express coordination within the relative clause the relative pronoun has to be repeated
  - *A customer inserts {a card that is valid and that has a code}.*

Interpretation Rules: Ambiguity

- scope of sentence negation *it is false that* extends to the end of a simple sentence

  {*It is false that a man waits*} *and a dog barks*.

- to express coordination within the scope of sentence negation the word *that* has to be repeated

  {*It is false that a man waits and that a dog barks*}.

- in *if*-*then*-sentences the scope of the *if*-part and the scope of the *then*-part extend to the end of a coordination

  {*If a man waits and a dog barks*} *then* {*a woman smiles and a cat sleeps*}.

Interpretation Rules: Ambiguity

- if an adverb can modify the preceding or the following verb then it refers to the preceding verb
  - *A customer who {enters a card manually} types a code*.
- textual position of a quantifier opens its scope that extends to the end of the sentence, or in a coordination to the end of the respective coordinated phrase
  - {*A customer types* {*every code*}}. $\exists\forall$
  - {*Every customer types* {*a code*}}. $\forall\exists$

Constraining Ambiguity: Plural Noun Phrases

- plural NPs are highly ambiguous
- of the many readings of plural NPs ACE provides only the collective and the distribute readings
- collective reading is the default
  - *A clerk enters 2 cards.*
- distributive reading is indicated by *each of*
  - *A clerk enters each of 2 cards.*

Constraining Ambiguity: Lexical Ambiguity

- verbs are highly ambiguous, since the same verb can appear as intransitive, transitive and ditransitive, and furthermore can occur with and without phrasal particles and prepositions as integral constituents
- to constrain this type of lexical ambiguity ACE expects that the phrasal particle of a phrasal verb (look up, drop out, shut down) and the preposition of a prepositional verb (look at, apply for) are hyphenated to the verb
  - *A steward waits-on the table.* (vs. *The food waits on the table*.)
  - *John looks-up an entry.* (vs. *John looks up the alley*.)
  - *What does John apply-for?* (vs. *John applies for the second time*.)

Constraining Ambiguity: Lexical Ambiguity

- hyphenation does not apply to ditransitive verbs since the prepositional complement is not adjacent to the verb and does not easily lead to ambiguity
  - *John gives a card to a clerk.*
  - *Who does John give a card to?*

- hyphenation can lead to ACE constructs not acceptable in full English
  - *There is an entry. John looks-up it.*

  that can easily be avoided using a definite noun phrase or a variable instead of a pronoun to express the anaphoric reference
  - *There is an entry. John looks-up the entry.*
  - *There is an entry E. John looks-up E.*

Summary of ACE's Disambiguation

- advantages of constructive disambiguation
  - automatic and efficient disambiguation
  - no use of contextual knowledge, domain knowledge, ontologies
  - simple, systematic, general, easy to learn interpretation rules
  - reliable, reproducible and thus intelligible behaviour
- open problems
  - rules do not always lead to natural interpretation
  - sometimes result in stilted English
  - Can we control all ambiguities with this strategy?
  - Does strategy scale up to a larger fragment of ACE?

Anaphoric References

- ACE texts are interrelated by anaphoric references, i.e. references to textually preceding noun phrases
- anaphoric references can be made by
  - proper names: *John*
  - pronouns: *it*, *itself*
  - definite noun phrases: *the card*, *the water*, *the red card*, *the man who waits*
  - variables: *the card X*, *X*
- *John has a customer. John inserts his card and types a code X. Bill sees X. He inserts his own card and types the code.*

Interpretation Rules: Anaphoric References

- proper names like *John* or *Mr-Miller* always denote the same object and thus serve as their own anaphoric references
- in all other cases resolution of anaphoric references is governed by
  - accessibility
  - recency
  - specificity
  - reflexivity

Interpretation Rules: Accessibility

- noun phrase is not accessible if it occurs in a negated sentence
  - *John does not enter a card. *It is correct.*
- noun phrase is not accessible if it occurs in a conditional sentence
  - *Every customer has a card. *It is correct.* (use instead: *Every customer has a card that is correct*.)
- but a noun phrase in the *if*-part of a conditional sentence is accessible in the *then*-part
  - *If a customer has a card then he enters it.*
- noun phrase in a disjunction is only accessible in subsequent disjuncts
  - *A customer enters a card or drops it. *It is dirty.*

Interpretation Rules: Pronominal References

- if the anaphor is a non-reflexive personal pronoun (*he*, *him*, …) or a non-reflexive possessive pronoun (*his*, …) then the anaphor is resolved with the most recent accessible noun phrase that agrees in gender and number, and that is not the subject of the sentence

- examples
  - *John has a card. Bob sees him and takes it.*
  - *John sees his wife*. (use: *John sees his own wife*.)

Interpretation Rules: Pronominal References

- if the anaphor is a reflexive personal pronoun (*herself*, …) or a reflexive possessive pronoun (*her own*, …) then the anaphor is resolved with the subject of the sentence in which the anaphor occurs if the subject agrees in gender and number with the anaphor

- example
  - Mary takes her own card and gets some money for herself.

Interpretation Rules: Definite Noun Phrases

- if the anaphor is a definite NP then it is resolved with the most recent and most specific accessible noun phrase that agrees in gender and number
- example
  - *There is a blue ball. There is a red ball. John sees the ball. Mary sees the blue ball.*
- pragmatics often requires using a definite noun phrase that is not meant anaphorically
  - if a definite NP cannot be resolved then it is interpreted as an indefinite noun phrase introducing a new object
  - *John goes to the bank*. (= *John goes to a bank*.)

Interpretation Rules: Variables

- if the anaphor is a variable then it is resolved with an accessible noun phrase that has the variable as apposition, or with a previously introduced "bare" variable

- example
  - *John has a card X and a card Y. Mary takes the card. Bob takes the card X. Harry takes Y.*
  - *John has X. X is not described.*

- example: predecessor is not accessible
  - *If a customer has a card C then the customer enters C. C is not valid.*
  - in this case the second occurrence of *C* introduces a new (bare) variable *C*

Relevant Documentation

- *ACE in a Nutshell* is a short overview of the ACE language
- *ACE Lexicon Specification* describes the allowed content words
- *ACE Construction Rules* lists the rules that determine which sentences belong to ACE
- *ACE Interpretation Rules* lists the rules that remove the ambiguity from the ACE sentences
- *ACE Troubleshooting Guide* describes how to use ACE, including how to avoid pitfalls
- *ACE Syntax Report* contains an abstract syntax of ACE
- *DRS Report* describes the DRS language

- this and more documentation is found at attempto.ifi.uzh.ch/site/docs/

To Take Home

- ACE is a first-order logic language with the syntax of a subset of English – thus human *and* machine understandable

- ACE does not introduce a division of labour between people who understand formal languages and those who don't – and thus eliminates a major communication problem

- ACE covers the essential part of the semantic continuum

  implicit – informal – formal for humans – formal for machines

  in one and the same notation

- ACE is ontologically neutral, i.e. does not require a priori world knowledge or a domain ontology – though both can be expressed in ACE

- ACE is neutral with regard to particular applications or methods

Other Controlled Languages

- http://en.wikipedia.org/wiki/Controlled_natural_language
- research
  - Schwitter (Macquarie): Processable English (PENG)
  - Sowa (VivoMind): Common Logic Controlled English (CLCE)
  - Pratt-Hartmann (Manchester): E2V
  - Dolbear et al. (Ordnance Survey): Rabbit
  - ...
- industry
  - Clark et al (Boeing): Computer-Processable Language (CPL)
  - ...

From ACE to First-Order Logic

- input: ACE text
- target: Extended Discourse Representation Structure (DRS)
  - uses syntactic variant of language of standard first-order logic
  - internal representation as term *drs(Referents, Conditions)* where *Referents* is a set of quantified variables and *Conditions* a set of logical conditions for *Referents*
- Attempto Parsing Engine (APE)
  - Definite Clause Grammar enhanced with feature structures (Prolog with ProFIT)
  - implements construction and interpretation rules
  - APE generates DRS, syntax tree, paraphrase etc.

Example DRS Representation
(Pretty-Printed APE Output)

Every company that buys at least 2 standard machines gets a discount.

PARAPHRASE

If a company X1 buys at least 2 standard machines then the company X1 gets a discount.

DRS

```
[]
   [A, B, C]
   object(A, company, countable, na, eq, 1)-1
   object(B, machine, countable, na, geq, 2)-1
   property(B, standard, pos)-1
   predicate(C, buy, A, B)-1
   =>
   [D, E]
   object(D, discount, countable, na, eq, 1)-1
   predicate(E, get, A, D)-1
```

Pretty Printed Example DRS

Every company that buys at least 2 standard machines gets a discount.

```
[]
  [A, B, C]
  object(A, company, countable, na, eq, 1)-1
  object(B, machine, countable, na, geq, 2)-1
  property(B, standard, pos)-1
  predicate(C, buy, A, B)-1
  =>
  [D, E]
  object(D, discount, countable, na, eq, 1)-1
  predicate(E, get, A, D)-1
```

Properties of DRS Representation

Only Predefined Relation Symbols

Every company that buys at least 2 standard machines gets a discount.

```
[]
  [A, B, C]
  object(A, company, countable, na, eq, 1)-1
  object(B, machine, countable, na, geq, 2)-1
  property(B, standard, pos)-1
  predicate(C, buy, A, B)-1
  =>
  [D, E]
  object(D, discount, countable, na, eq, 1)-1
  predicate(E, get, A, D)-1
```

Properties of DRS Representation

Predicates as Arguments

Every company that buys at least 2 standard machines gets a discount.

```
[]
  [A, B, C]
  object(A, company, countable, na, eq, 1)-1
  object(B, machine, countable, na, geq, 2)-1
  property(B, standard, pos)-1
  predicate(C, buy, A, B)-1
  =>
  [D, E]
  object(D, discount, countable, na, eq, 1)-1
  predicate(E, get, A, D)-1
```

Properties of DRS Representation

Quantity Information

Every company that buys at least 2 standard machines gets a discount.

```
[]
  [A, B, C]
  object(A, company, countable, na, eq, 1)-1
  object(B, machine, countable, na, geq, 2)-1
  property(B, standard, pos)-1
  predicate(C, buy, A, B)-1
  =>
  [D, E]
  object(D, discount, countable, na, eq, 1)-1
  predicate(E, get, A, D)-1
```

Properties of DRS Representation

Indices for Tracking

Every company that buys at least 2 standard machines gets a discount.

```
[]
  [A, B, C]
  object(A, company, countable, na, eq, 1)-1
  object(B, machine, countable, na, geq, 2)-1
  property(B, standard, pos)-1
  predicate(C, buy, A, B)-1
  =>
  [D, E]
  object(D, discount, countable, na, eq, 1)-1
  predicate(E, get, A, D)-1
```

Summary of DRS Representation

- advantages of DRS representation
  - DRS: integrate discourse anaphora
  - first-order: eases automated deduction and reusability
  - reification: possible quantification over predicates in first-order logic
  - plurals: represent plurals in first-order logic
- DRSs have been translated into other first-order languages
- via DRSs tools can make use of ACE as interface language

ACE Tools

- Attempto Parsing Engine (APE)
- ACE Editor
- ACE Reasoner (RACE)
- ACE View Protégé Plug-in
- AceWiki
- AceRules

Attempto Parsing Engine (APE)

- for syntactically correct texts outputs the analysis of the text
  - tokens
  - syntax trees
  - paraphrase
  - discourse representation structure
  - translation of DRS into other first-order languages
- for erroneous texts
  - detects syntactic errors and unknown words in an ACE text
  - generates error and warning messages indicating the location and the possible causes of the errors, and suggesting remedies

Attempto Parsing Engine (APE)

- APE can be accessed
  - by a web-service (attempto.ifi.uzh.ch/site/docs/ape_webservice.html)
  - by a web-client (attempto.ifi.uzh.ch/site/tools/ or directly attempto.ifi.uzh.ch/ape/)
  - from Java programs (Attempto Java Packages downloadable under GNU LGPL from attempto.ifi.uzh.ch/site/downloads/)
- all APE interfaces are fully documented
- source code of APE plus some related tools is available under the GNU LGPL at attempto.ifi.uzh.ch/site/downloads/

Hide menu | Help

Show ☑ Input text ☑ Paraphrase ☑ DRS ☐ DRS XML ☐ FOL ☐ PNF ☐ OWL FSS ☐ OWL RDF ☐ Tokens ☐ Syntax

Options ☐ Guess unknown words ☐ Do not use Clex

Lexicon ☐ Reload the lexicon from URL

If a talk ends then everybody can ask a question.

↑ ↓ Analyse

overall: 0.469 sec (tokenizer: 0.000 parser: 0.010 refres: 0.000) :: Thu Sep 04 2008 17:42:37 GMT+0200 (CEST)

If a talk ends then everybody can ask a question.

PARAPHRASE

If a talk ends then if there is somebody X1 then it is possible that X1 asks a question.

DRS

```
[]
   [A, B]
   object(A, talk, countable, na, eq, 1)-1
   predicate(B, end, A)-1
   =>
   []
      [C]
      object(C, somebody, countable, na, eq, 1)-1
      =>
      []
         <|>
         [D, E]
         object(D, question, countable, na, eq, 1)-1
         predicate(E, ask, C, D)-1
```

Hide menu | Help

Show ☑ Input text ☑ Paraphrase ☑ DRS ☐ DRS XML ☐ FOL ☐ PNF ☐ OWL FSS ☐ OWL RDF ☐ Tokens ☐ Syntax
Options ☐ Guess unknown words ☐ Do not use Clex
Lexicon ☐ Reload the lexicon from URL

If a talk ends then everybody can aks a question.

↑ ↓ Analyse

overall: 0.086 sec (tokenizer: 0.010 parser: 0.010 refres: 0.000) :: Thu Sep 04 2008 17:45:18 GMT+0200 (CEST)

	Type	Sentence	Problem	Suggestion
error	sentence	1	If a talk ends then everybody can <> aks a question.	This is the first sentence that was not ACE. The sign <> indicates the position where parsing failed.
error	word		aks	ask

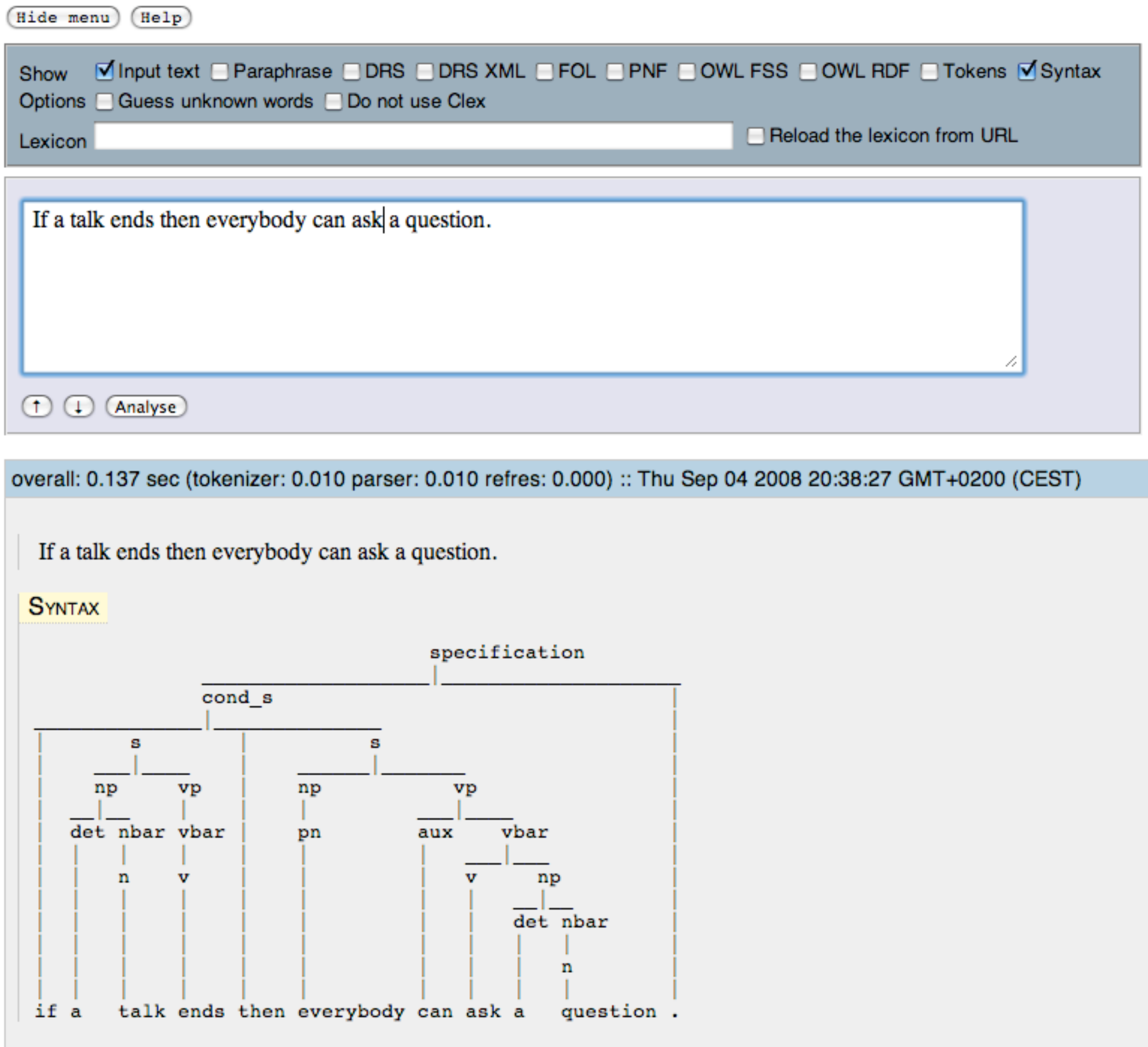
If a talk ends then everybody can aks a question.

PARAPHRASE

NOT IMPLEMENTED

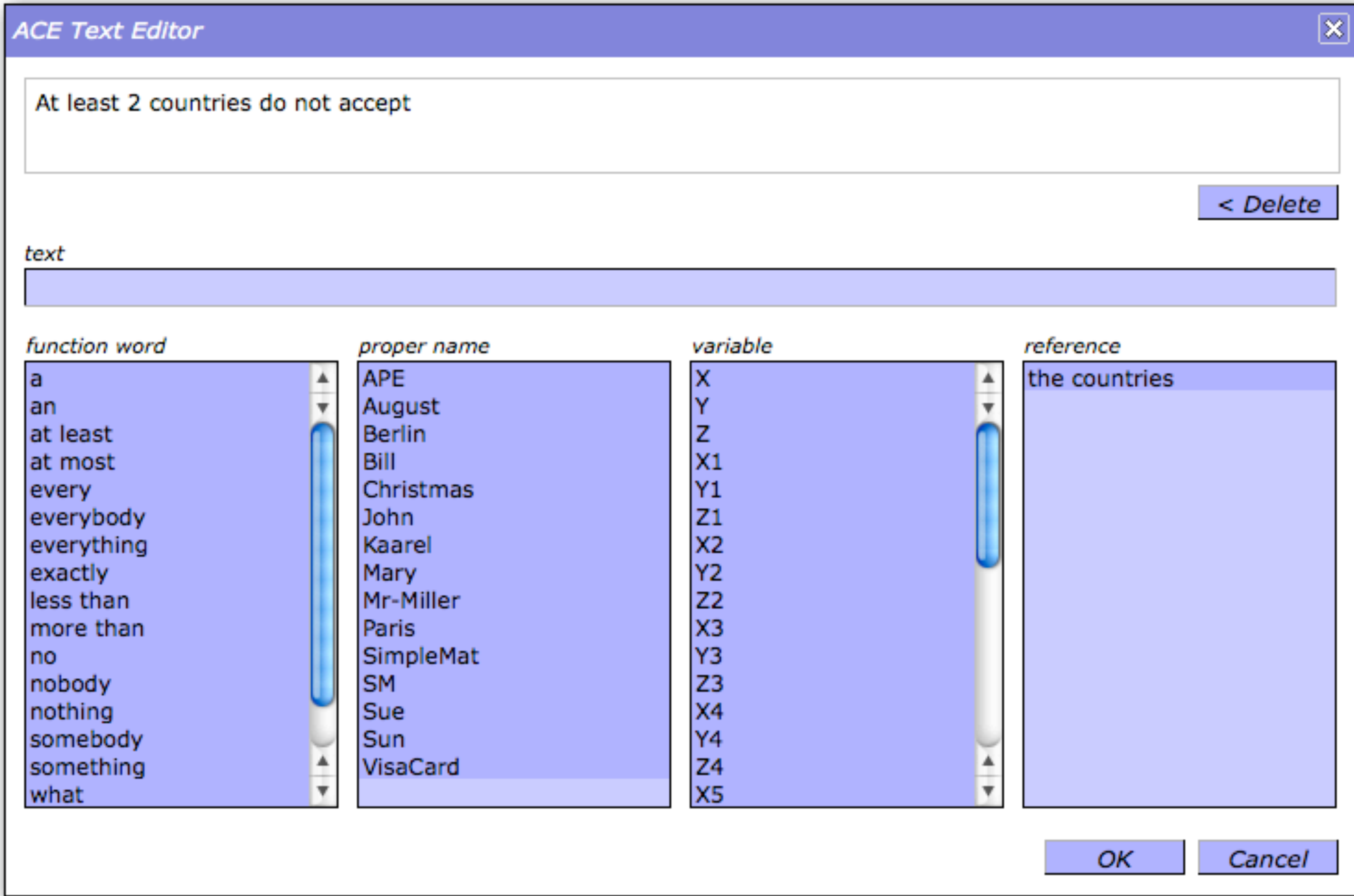
DRS

```
No conditions
[]
```


Hide menu
Help
Show
Input text
Paraphrase
DRS
DRS XML
FOL
PNF
OWL FSS
OWL RDF
Tokens
Syntax
Options
Guess unknown words
Do not use Clex
Lexicon
Reload the lexicon from URL
If a talk ends then everybody can ask a question.
Analyse
overall: 0.137 sec (tokenizer: 0.010 parser: 0.010 refres: 0.000) :: Thu Sep 04 2008 20:38:27 GMT+0200 (CEST)
If a talk ends then everybody can ask a question.
Syntax
specification
cond_s
s
s
np
vp
np
vp
det
nbar
vbar
pn
aux
vbar
n
v
v
np
det
nbar
n
if a talk ends then everybody can ask a question .

ACE Editor

- APE requires users to learn and to recall the ACE construction and interpretation rules
- ACE Editor is an experimental predictive editor that helps users to construct syntactically and lexically correct ACE texts by just clicking on words and word classes
- alternatively users can freely input ACE texts
- ACE Editor grew out of the AceWiki development
- ACE Editor can be accessed via a web-client (attempto.ifi.uzh.ch/aceeditor/)


ACE Text Editor
At least 2 countries do not accept
< Delete
text
function word
a
an
at least
at most
every
everybody
everything
exactly
less than
more than
no
nobody
nothing
somebody
something
what
proper name
APE
August
Berlin
Bill
Christmas
John
Kaarel
Mary
Mr-Miller
Paris
SimpleMat
SM
Sue
Sun
VisaCard
variable
X
Y
Z
X1
Y1
Z1
X2
Y2
Z2
X3
Y3
Z3
X4
Y4
Z4
X5
reference
the countries
OK
Cancel

ACE Reasoner (RACE)

- RACE performs deductions on ACE texts
- basic proof procedure: if an ACE text (= set of sentences) is inconsistent then RACE identifies all minimal inconsistent subsets
- variants of the basic proof procedure allow RACE to
  - prove that one ACE text (axioms) entails another ACE text (theorems)
  - answer ACE queries on the basis of an ACE text
- RACE provides a proof justification in ACE
- RACE finds all proofs
- RACE uses domain-independent auxiliary axioms to reason about plurals, natural numbers, equality etc.

Requirements for RACE

- all input and output in ACE
- generate all proofs
- give a user-friendly justification of a proof
- allow for auxiliary first-order axioms to express background knowledge that cannot (easily) be expressed in ACE
- interface to evaluable functions
- combine theorem proving with model generation
- hide internal working from casual user

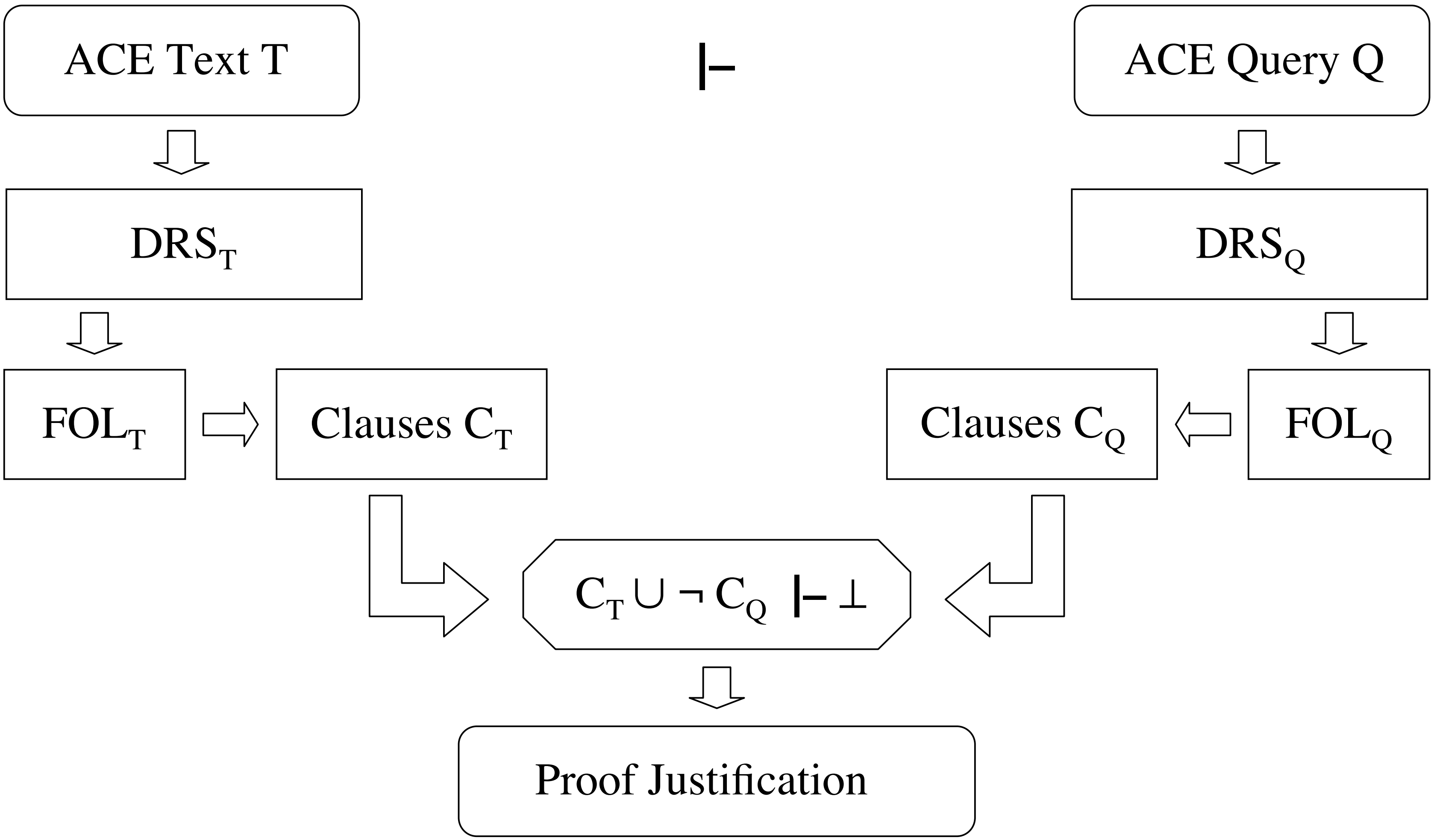
A Basis for RACE

- Satchmo (Manthey & Bry 1988)
  - basically a model generator
  - can also be used a theorem prover
  - uses first-order clauses Body → Head
  - generates minimal finite Herbrand models of clauses (if existent)
  - correct for unsatisfiability of range-restricted clauses
  - complete for unsatisfiability if used level-saturated
  - efficient Prolog core allowing for ...
  - ... local extensions and modifications in Prolog

RACE Extensions of Satchmo

- RACE extensions should preserve Satchmo's correctness, completeness and efficiency
- RACE generates all proofs
  - Satchmo stops immediately if it detects unsatisfiability
  - RACE finds *all* minimal unsatisfiable subsets of clauses
- RACE gives a justification of every proof
  - RACE collects indices of logical atoms used for a proof
  - RACE generates for each proof a report showing which ACE sentences were used to derive which ACE query
- input and output in ACE

Structure of RACE



ACE Reasoner (RACE)

- RACE can be accessed by
  - web-service (attempto.ifi.uzh.ch/site/docs/race_webservice.html)
  - web-client (attempto.ifi.uzh.ch/site/tools/ or directly attempto.ifi.uzh.ch/race/)
- all RACE interfaces are fully documented

Show Parameters | Show Help

Axioms

Every man is a human. Every woman is a human.
Mary is a woman. John is a man. John is not a human.

Check Consistency | Prove | Answer Query

Check Consistency

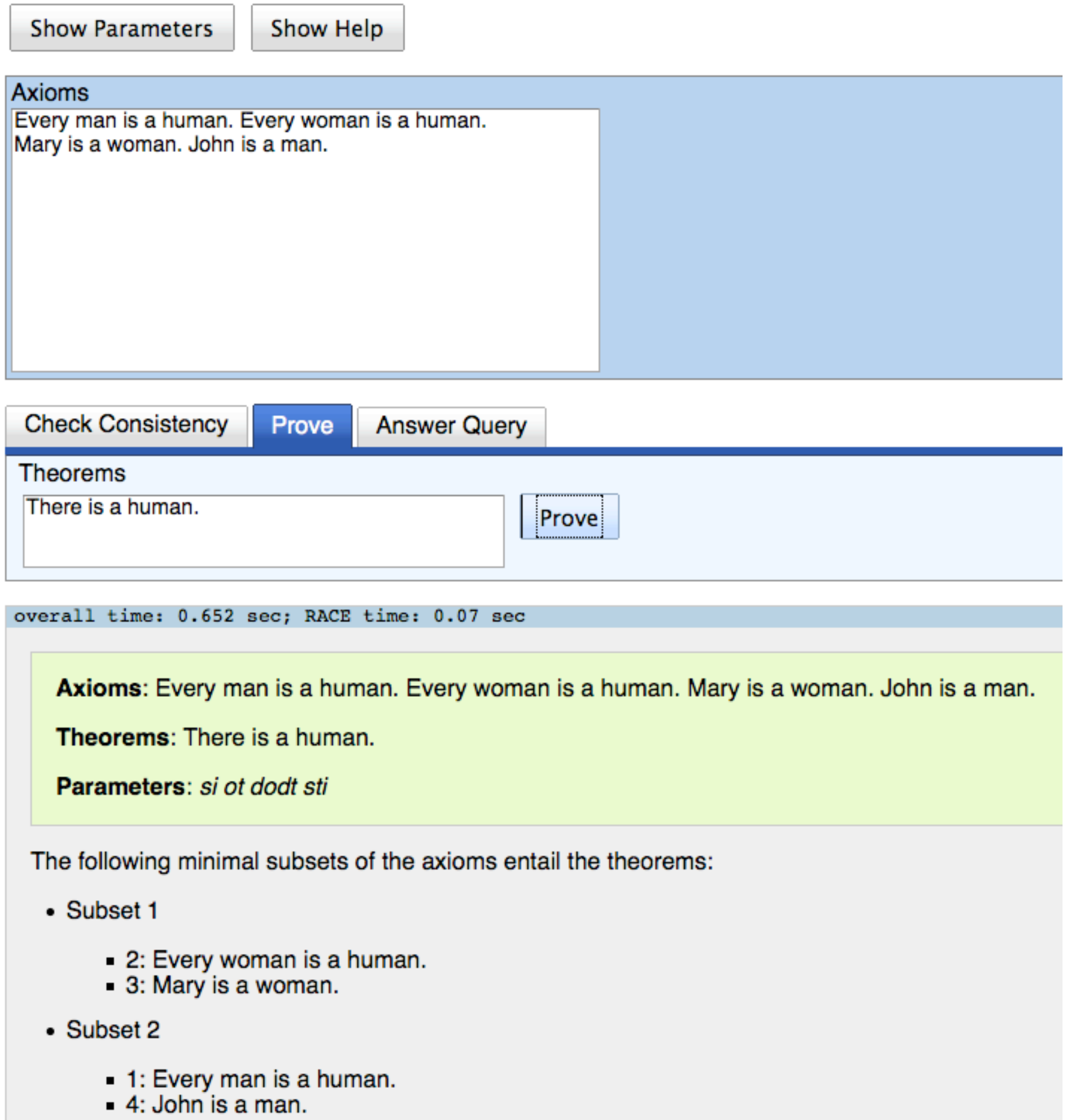
`overall time: 0.703 sec; RACE time: 0.12 sec`

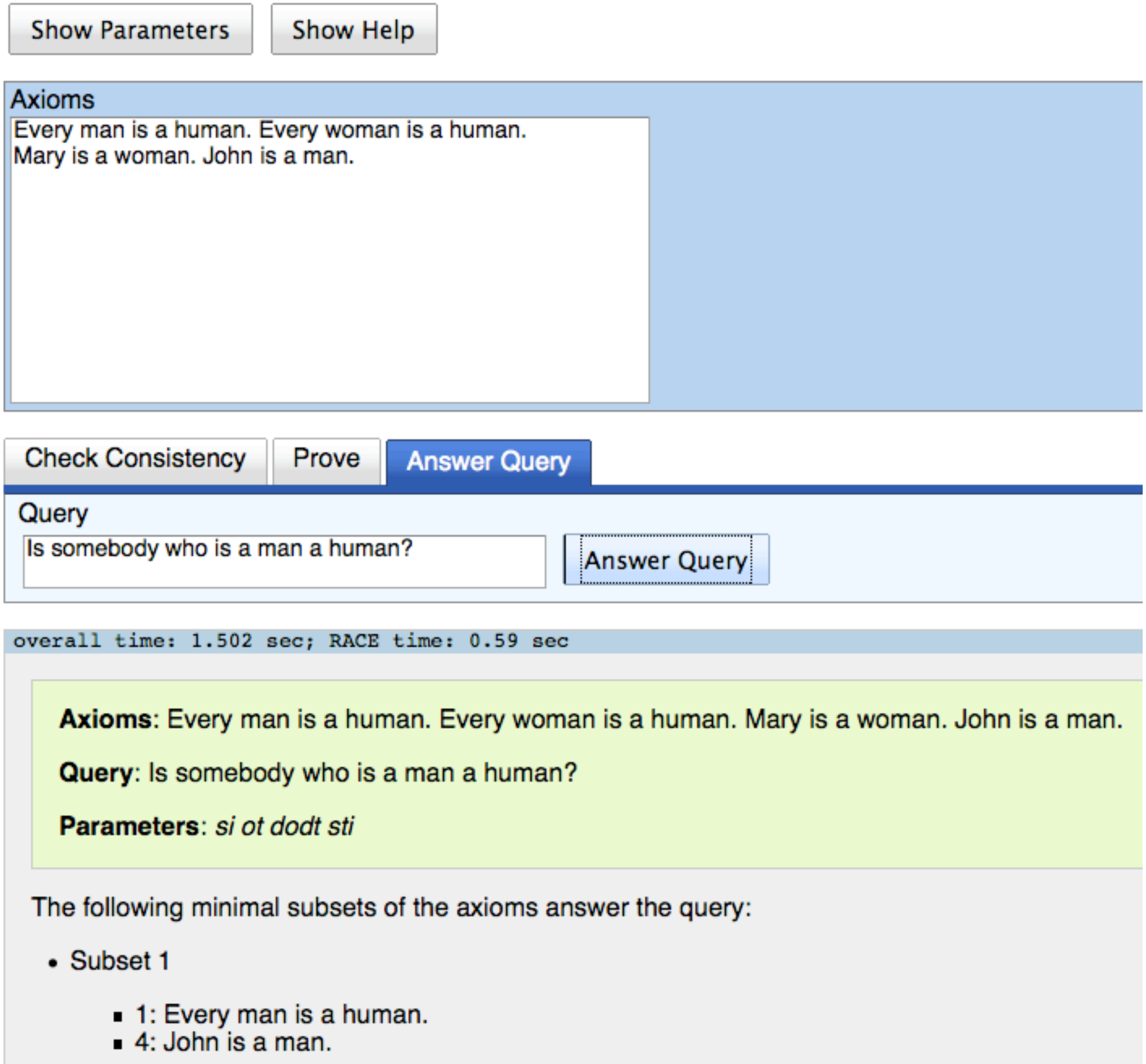
Axioms: Every man is a human. Every woman is a human. Mary is a woman. John is a man. John is not a human.

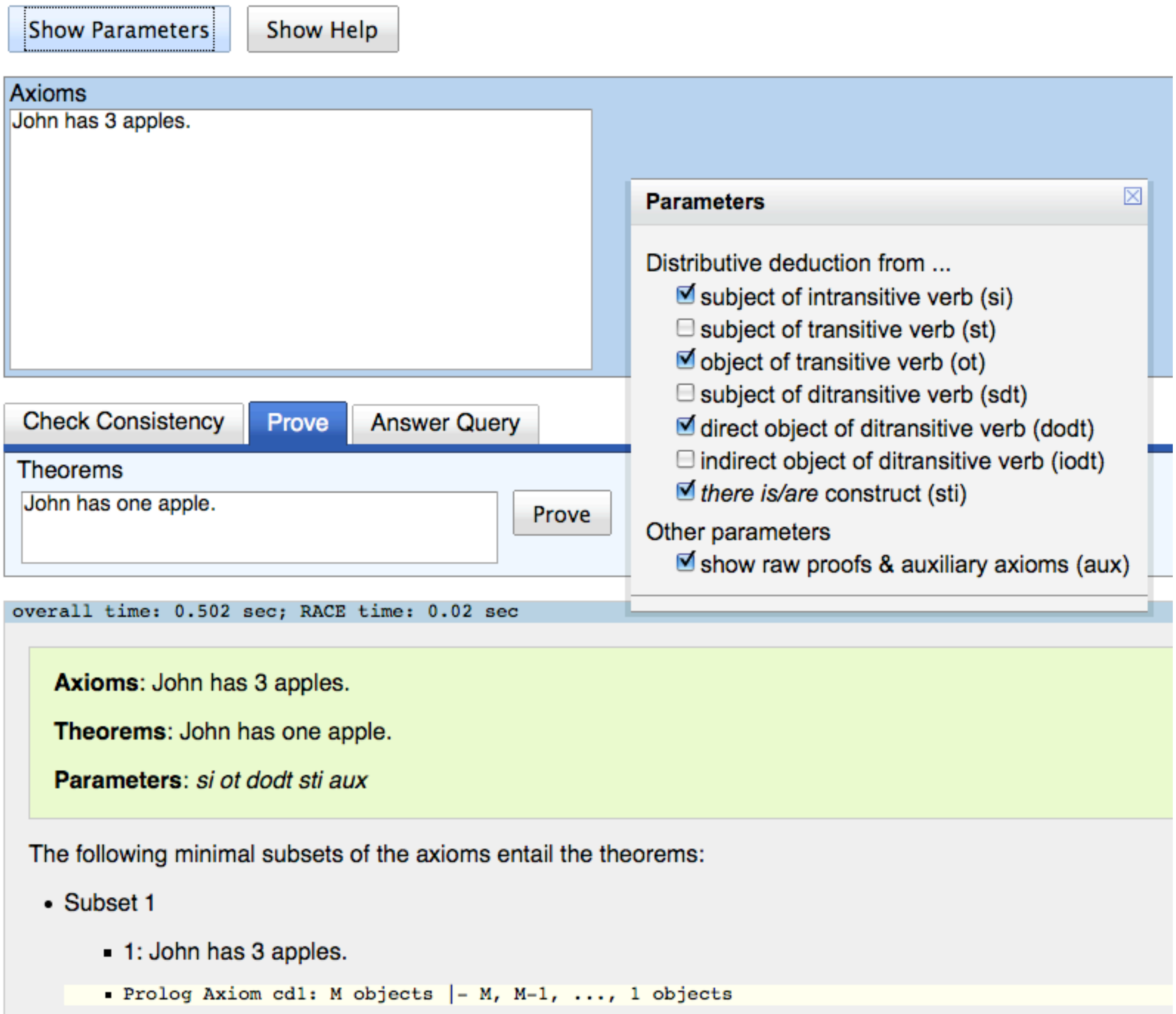
Parameters: *si ot dodt sti*

Axioms are inconsistent. The following minimal subsets of the axioms cause inconsistency:

- Subset 1
  - 1: Every man is a human.
  - 4: John is a man.
  - 5: John is not a human.


Show Parameters
Show Help
Axioms
Every man is a human. Every woman is a human.
Mary is a woman. John is a man.
Check Consistency
Prove
Answer Query
Theorems
There is a human.
Prove
overall time: 0.652 sec; RACE time: 0.07 sec
Axioms: Every man is a human. Every woman is a human. Mary is a woman. John is a man.
Theorems: There is a human.
Parameters: si ot dodt sti
The following minimal subsets of the axioms entail the theorems:
Subset 1
2: Every woman is a human.
3: Mary is a woman.
Subset 2
1: Every man is a human.
4: John is a man.


Show Parameters
Show Help
Axioms
Every man is a human. Every woman is a human.
Mary is a woman. John is a man.
Check Consistency
Prove
Answer Query
Query
Is somebody who is a man a human?
Answer Query
overall time: 1.502 sec; RACE time: 0.59 sec
Axioms: Every man is a human. Every woman is a human. Mary is a woman. John is a man.
Query: Is somebody who is a man a human?
Parameters: si ot dodt sti
The following minimal subsets of the axioms answer the query:
Subset 1
1: Every man is a human.
4: John is a man.


Show Parameters
Show Help
Axioms
John has 3 apples.
Parameters
Distributive deduction from ...
subject of intransitive verb (si)
subject of transitive verb (st)
object of transitive verb (ot)
subject of ditransitive verb (sdt)
direct object of ditransitive verb (dodt)
indirect object of ditransitive verb (iodt)
there is/are construct (sti)
Other parameters
show raw proofs & auxiliary axioms (aux)
Check Consistency
Prove
Answer Query
Theorems
John has one apple.
Prove
overall time: 0.502 sec; RACE time: 0.02 sec
Axioms: John has 3 apples.
Theorems: John has one apple.
Parameters: si ot dodt sti aux
The following minimal subsets of the axioms entail the theorems:
Subset 1
1: John has 3 apples.
Prolog Axiom cd1: M objects |- M, M-1, ..., 1 objects

ACE View: Motivation

- people need formal ontologies
- people often need high expressivity
- ontology languages (OWL, F-Logic, SWRL) deliver this expressivity, but their syntax is complicated
- so, there is a usability problem
  - front-end tools have failed to solve this problem
  - as a result: domain experts need knowledge engineers

ACE View: Problems with OWL

- OWL has many syntaxes
  - RDF/XML
  - other RDF syntaxes (such as N3, Turtle, etc.)
  - Functional-Style Syntax
  - Manchester OWL Syntax (MOS)
  - standard Description Logic syntax
- none of them, except for the new Manchester OWL Syntax, have been invented with domain experts in mind

ACE View: Problems with Ontology Editors

- match the syntax of the underlying OWL instead of hiding it
- keep rules (SWRL) and ontology (OWL) separate
- poor visualization, just a named class tree
- failure to enforce good naming style (e.g. singular vs plural), or keep axioms simple (to be readable to other users)
- names cannot be used unless defined first
- simple things are hard to enter
  - *John likes everybody who owns a car*.
  - own some car SubClassOf inv(like) some {John}

ACE View

- ACE as an alternative syntax for OWL and related languages
- ACE View
  - ontology and rule editor
  - uses ACE for the user interface
  - creates, views and edits OWL 2 ontologies and SWRL rulesets
- implemented as plug-in for the Protégé ontology editor
- description at www.cl.uzh.ch/kalju/ACE_View/

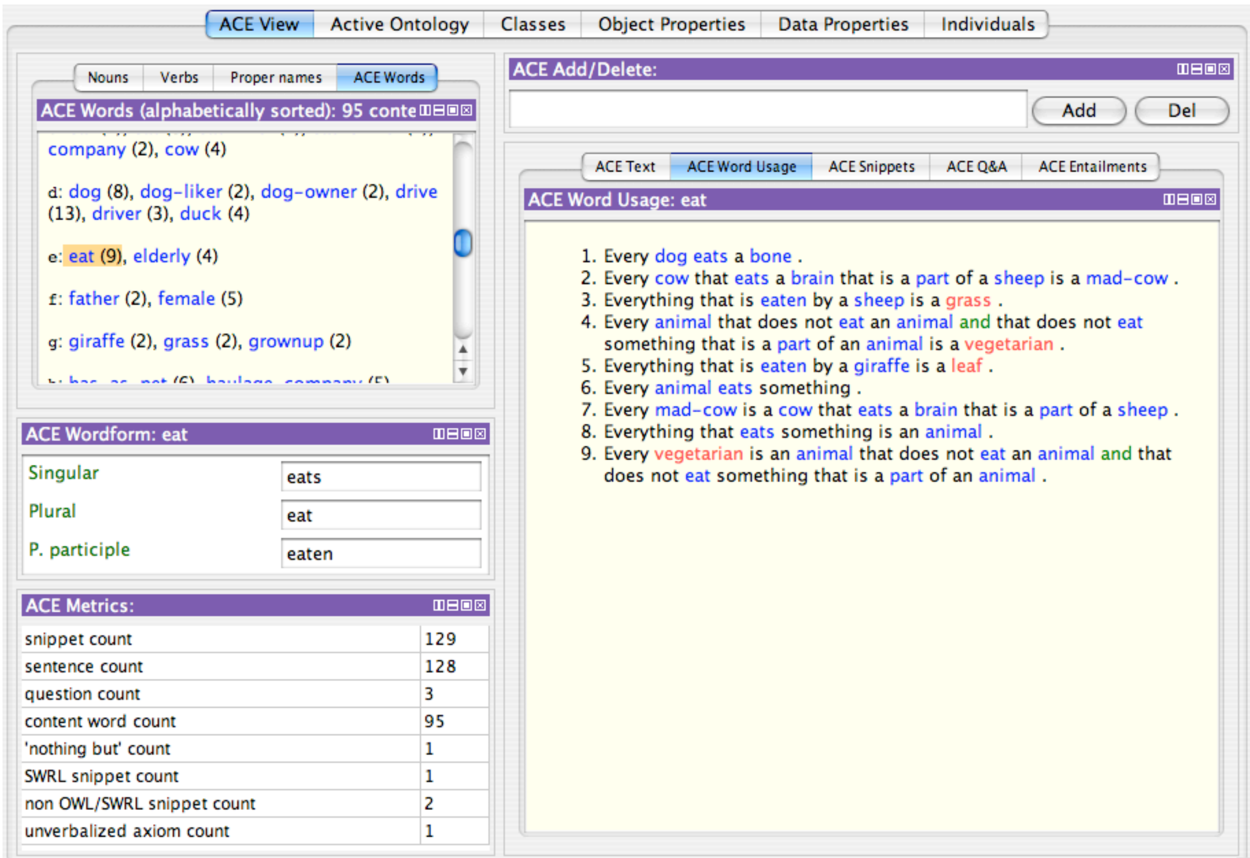
Aligning ACE with OWL

- OWL elements vs ACE elements
  - class description is a noun phrase
  - named class is a noun
  - (object) property is a transitive verb
  - inverse property is a passive verb
  - data properties are transitive verbs or *of*-constructions whose object is a data item (number or string)
  - individual is a proper name
  - axiom is a sentence or a set of sentences
  - relative clauses can express complex class descriptions ...
  - ... but there are limitations to express scopes of deeply nested OWL class descriptions

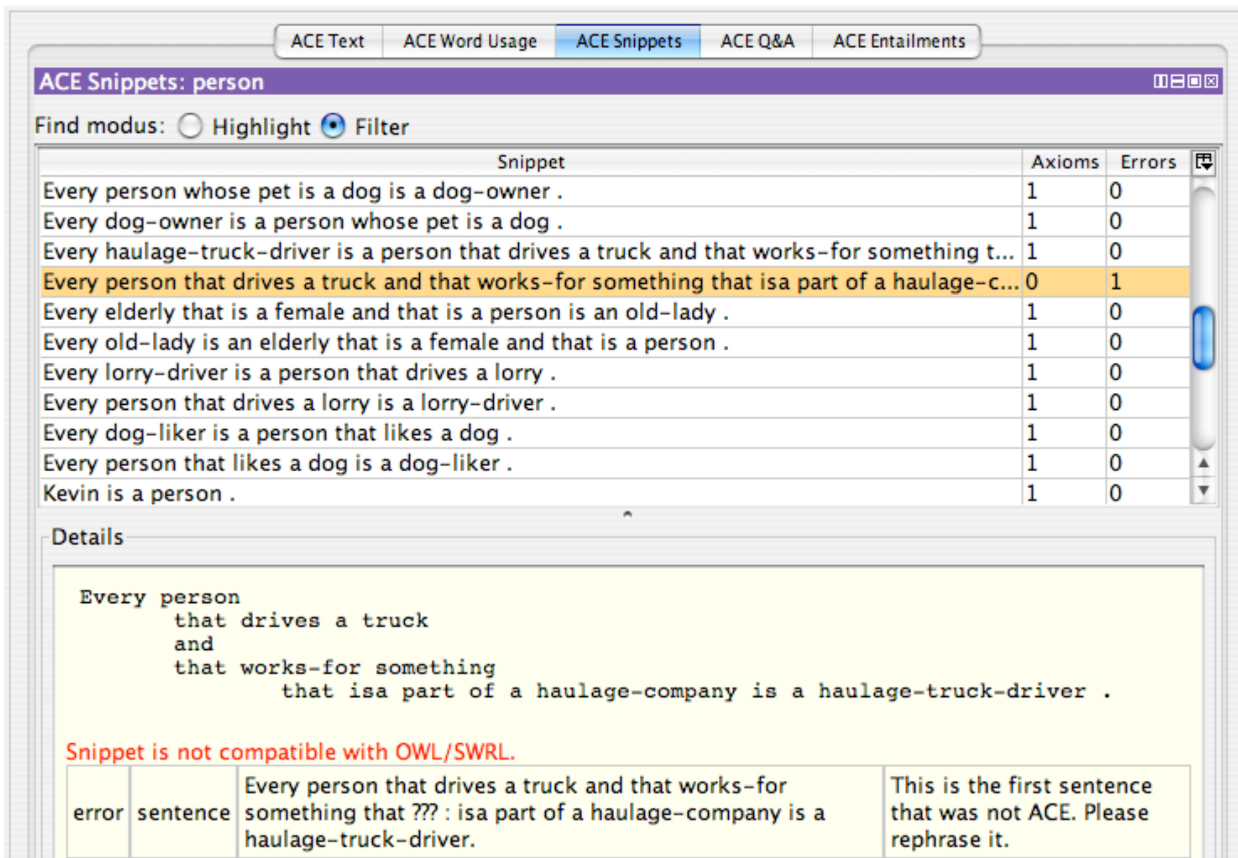
ACE View

- ontology and rule editing using ACE
- input can be actually full English, but only OWL/SWRL-compatible sentences participate in reasoning
- plain text and "index" views to the ontology
- "semantic feedback" in ACE:
  - entailments
  - entailment explanation
  - query-answering
- implementation
  - integrates translators ACE→OWL/SWRL and OWL→ACE
  - implemented as a plug-in for Protégé 4 …
  - … which makes it easy to switch between the "ACE View" and the traditional "Protégé view"

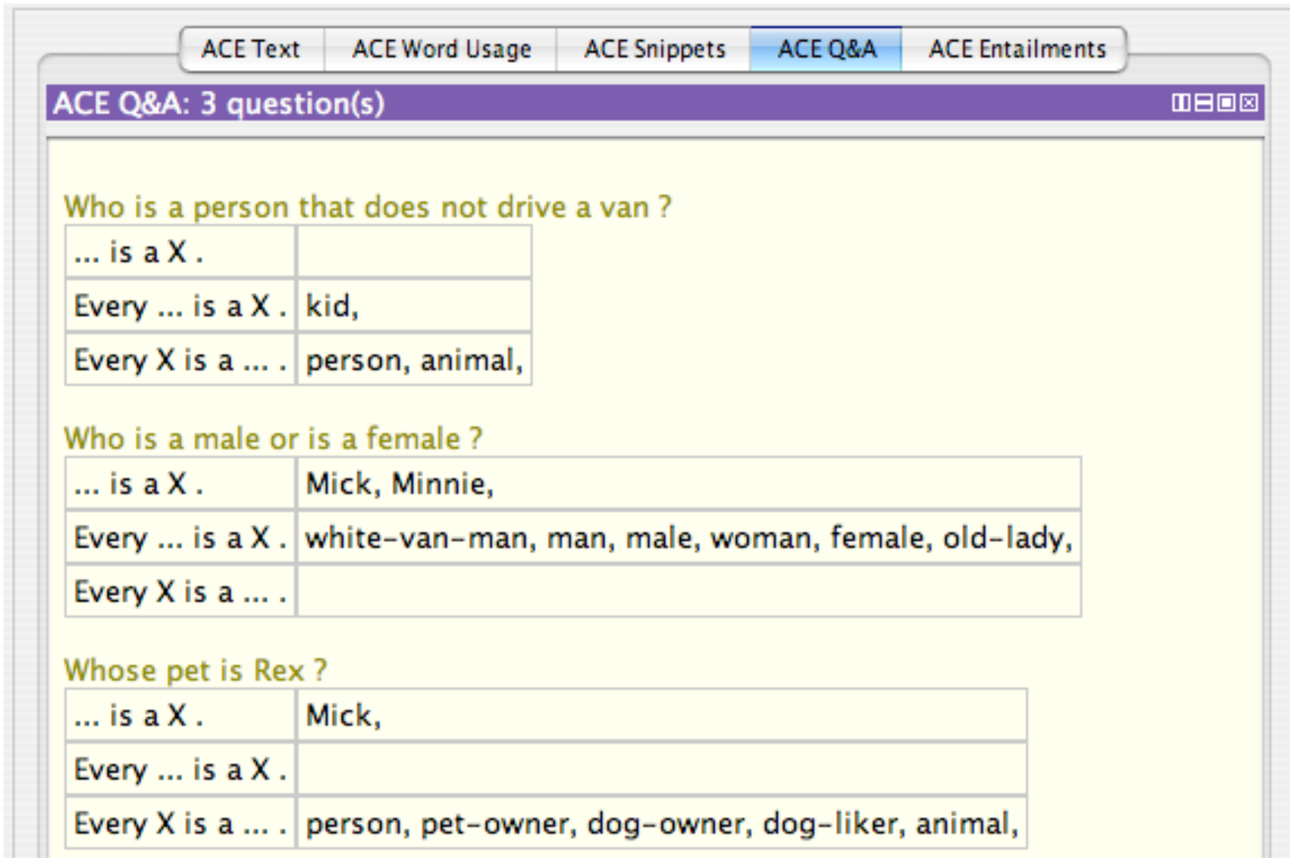
ACE View: Various Views



ACE View: Snippets



ACE View: Q&A



Who is a person that does not drive a van ?

... is a X .	
Every ... is a X .	kid,
Every X is a	person, animal,

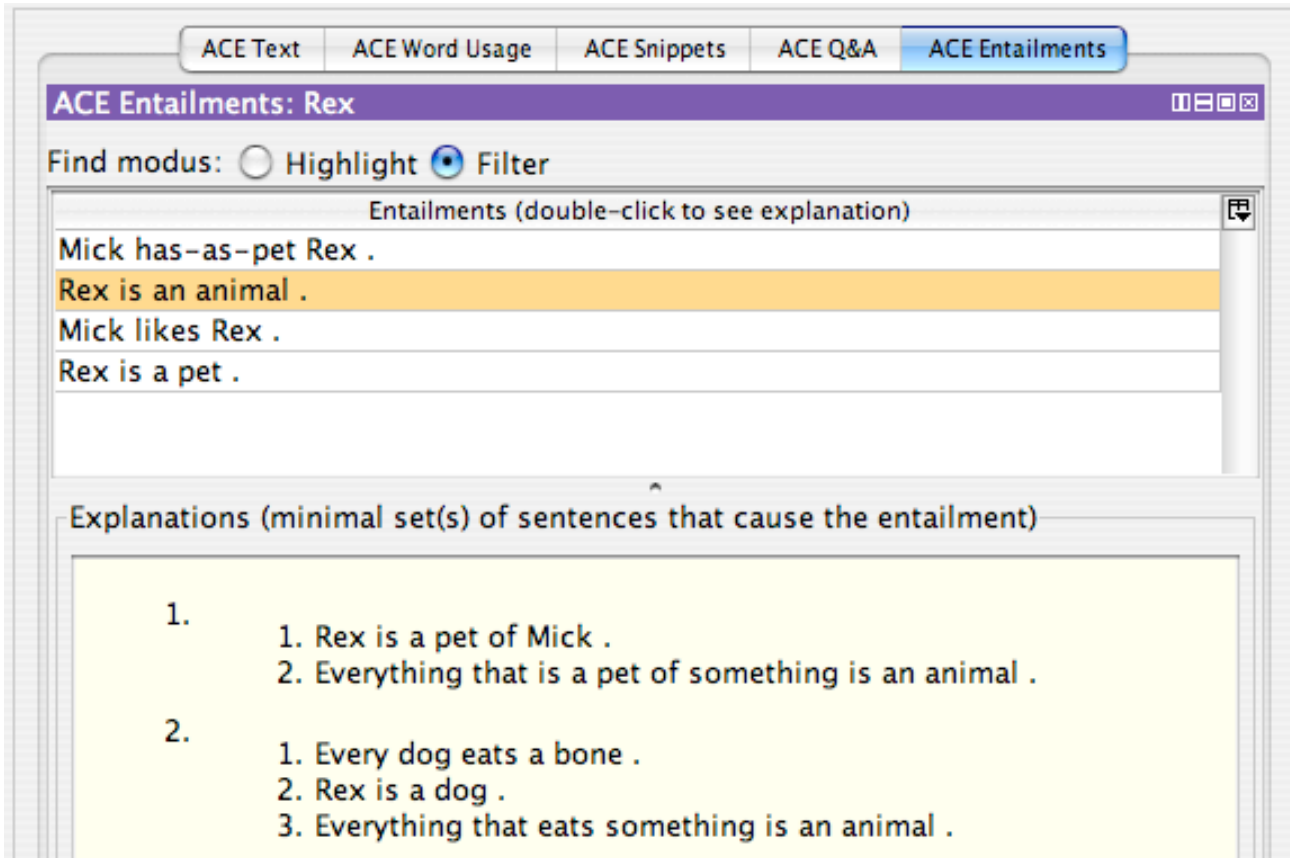
Who is a male or is a female ?

... is a X .	Mick, Minnie,
Every ... is a X .	white-van-man, man, male, woman, female, old-lady,
Every X is a	

Whose pet is Rex ?

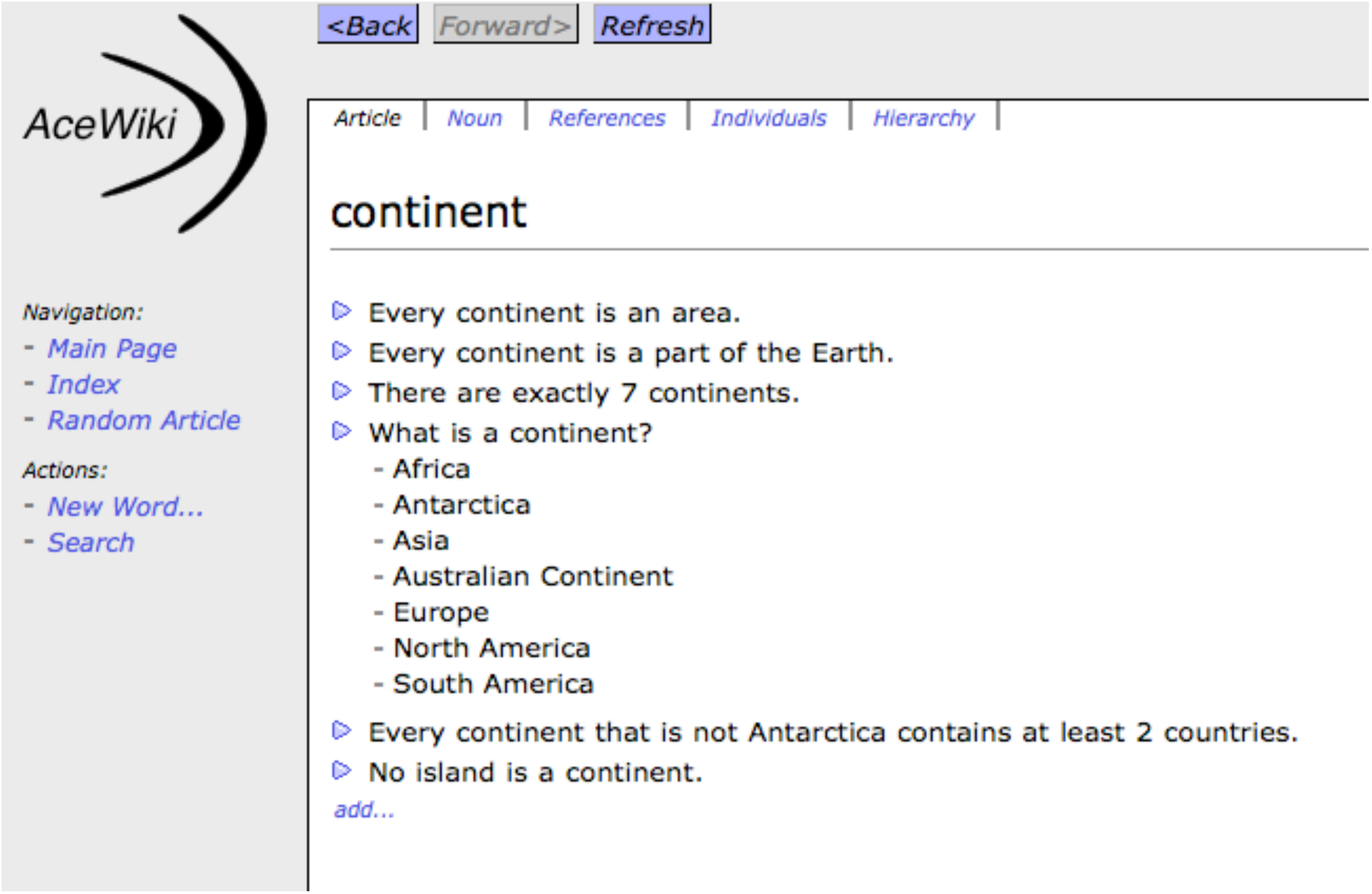
... is a X .	Mick,
Every ... is a X .	
Every X is a	person, pet-owner, dog-owner, dog-liker, animal,

ACE View: Entailments

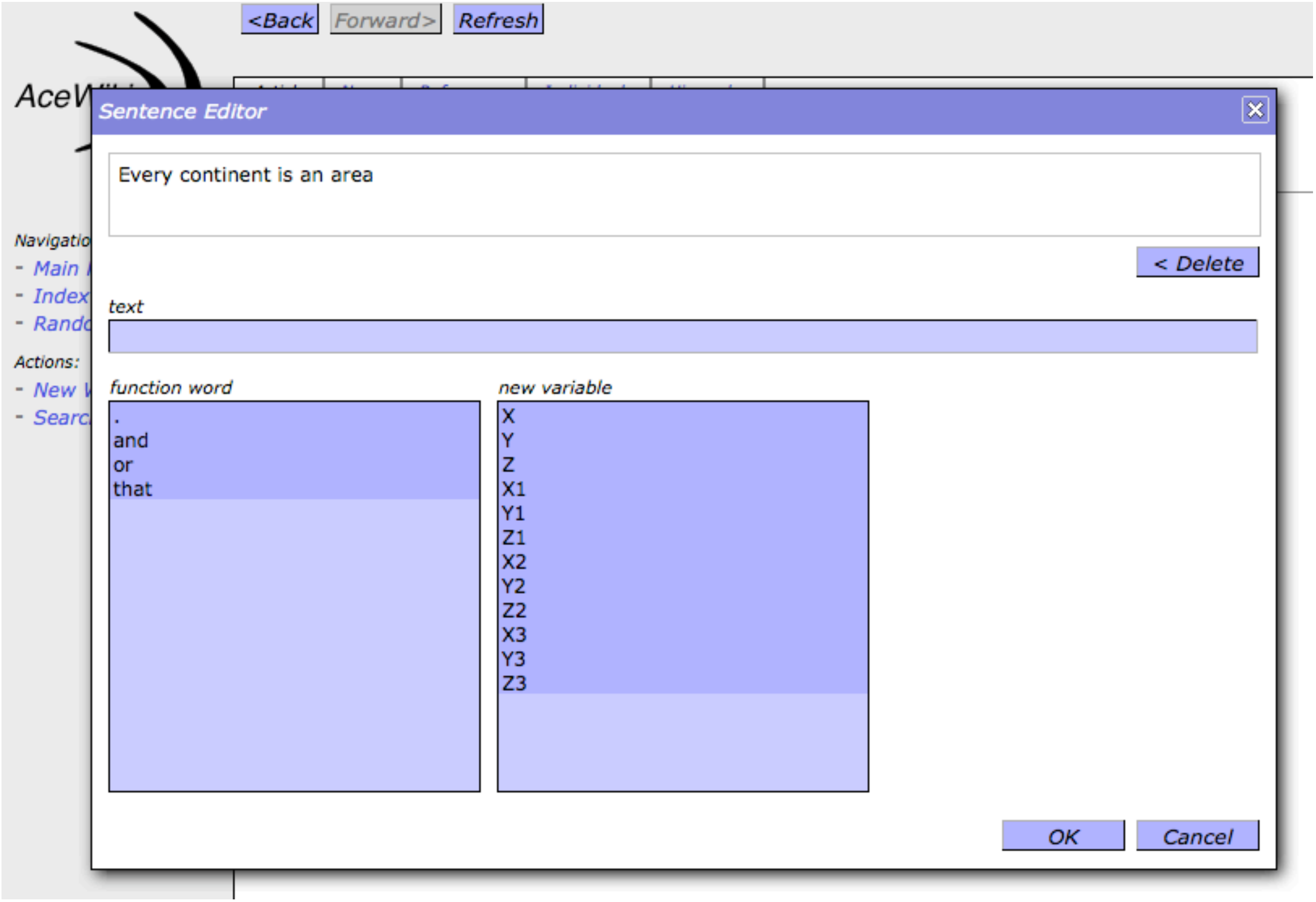


AceWiki

- shortcomings of many existing semantic wikis
  - hard to understand for people who are not familiar with formal languages
  - relatively inexpressive (mostly subject-predicate-object structures)
- AceWiki offers an alternative
  - uses ACE to express wiki articles
  - articles are formal but still readable by people
  - ACE covers a large part of FOL and is highly expressive
  - collaborative ontology management in ACE
- AceWiki demos and documentation (attempto.ifi.uzh.ch/acewiki/)


<Back
Forward>
Refresh
AceWiki
Article
Noun
References
Individuals
Hierarchy
continent
Every continent is an area.
Every continent is a part of the Earth.
There are exactly 7 continents.
What is a continent?
- Africa
- Antarctica
- Asia
- Australian Continent
- Europe
- North America
- South America
Every continent that is not Antarctica contains at least 2 countries.
No island is a continent.
add...
Navigation:
- Main Page
- Index
- Random Article
Actions:
- New Word...
- Search


AceWiki
<Back
Forward>
Refresh
Article
Noun
References
Individuals
Hierarchy
continent
Navigation:
- Main Page
- Index
- Random Article
Actions:
- New Word...
- Search
Edit...
Add...
Delete
Details
Logic
area.
part of the Earth.
continents.
- Antarctica
- Asia
- Australian Continent
- Europe
- North America
- South America
Every continent that is not Antarctica contains at least 2 countries.
No island is a continent.
add...


<Back
Forward>
Refresh
Sentence Editor
Every continent is an area
< Delete
text
function word
.
and
or
that
new variable
X
Y
Z
X1
Y1
Z1
X2
Y2
Z2
X3
Y3
Z3
OK
Cancel

AceWiki: Reasoning

- AceWiki currently uses the OWL reasoner Pellet
- AceWiki marks sentences that make a text inconsistent
- ACE sentences that cannot be translated to OWL do not take part in reasoning
- AceWiki can answer questions
- AceWiki can infer class membership and hierarchies

AceRules

- domain specialists that are supposed to create and/or validate rules are often not familiar with formal languages
- verbalization of the rules in natural language becomes necessary
- translation of rules into NL (and backwards) is complicated and a potential source of errors
- AceRules offers an alternative
  - expresses rules in ACE
  - rules expressed in ACE are formal and still readable by humans

AceRules: Examples

- John is an important customer.

  customer('John') ←

  important('John') ←

- No clerk is a customer.

  -customer(A) ← clerk(A)

- Everyone who is not provably a criminal is trustworthy.

  trustworthy(A) ← ~criminal(A)

- If a resource is public then every user can download the resource.

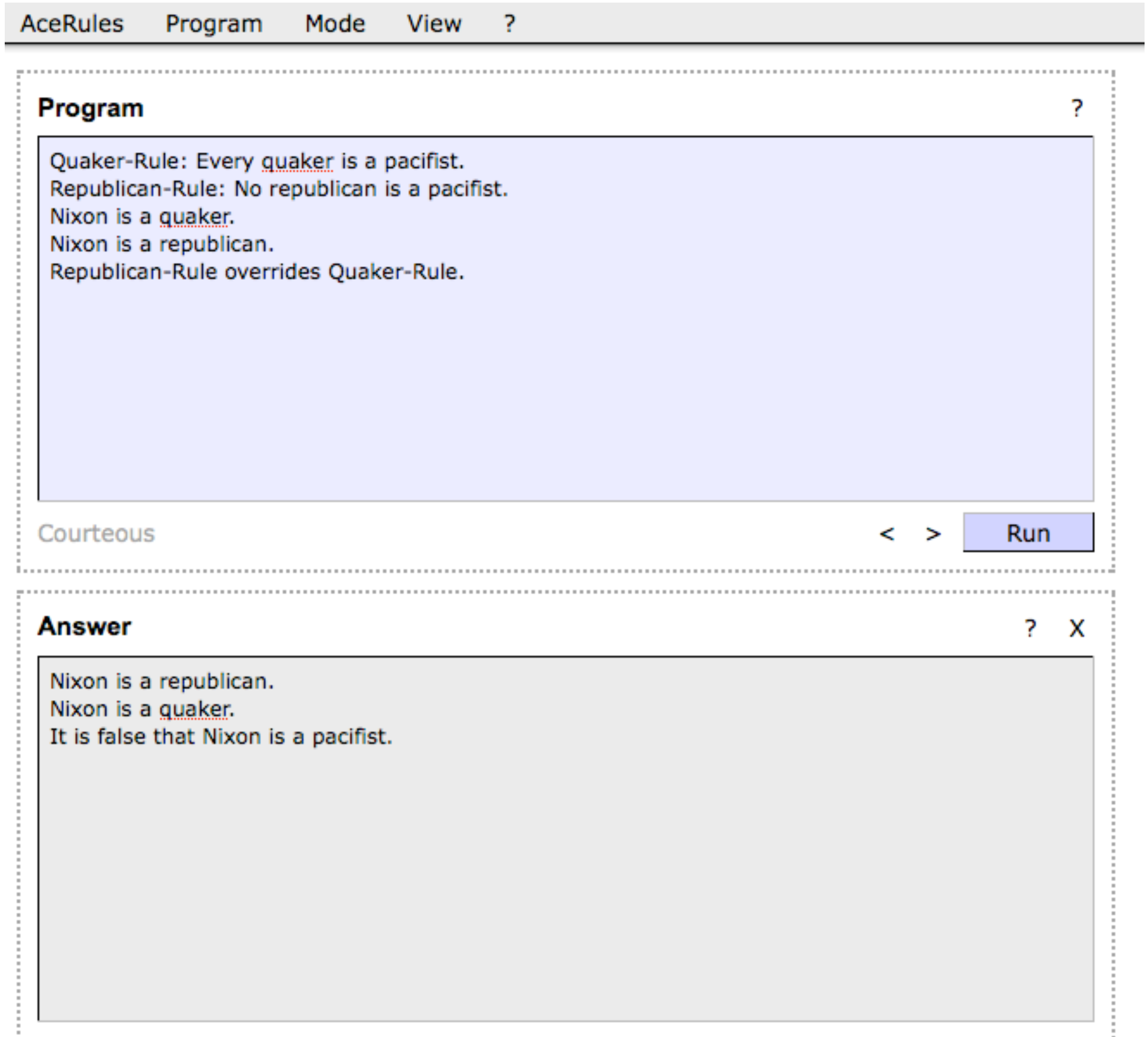
  can(download(A,B)) ← user(A), resource(B), public(B)

- If a user is authenticated and has a subscription and there is a resource that is available for the subscription then the user can download the resource.

  can(download(A,B)) ← be_available_for(B,C), have(A,C), resource(B), subscription(C), user(A), authenticated(A)

AceRules: Interpreter

- AceRules uses forward-reasoning
- semantics of rules is exchangable
- currently supported semantics
  - courteous logic programming
  - stable models
  - stable models with strong negation
- AceRules is fully documented and can be used via
  - web-service (attempto.ifi.uzh.ch/site/docs/acerules_webservice.html)
  - web-client (attempto.ifi.uzh.ch/acerules/)


AceRules
Program
Mode
View
?
Program
Quaker-Rule: Every quaker is a pacifist.
Republican-Rule: No republican is a pacifist.
Nixon is a quaker.
Nixon is a republican.
Republican-Rule overrides Quaker-Rule.
Courteous
<
>
Run
Answer
X
Nixon is a republican.
Nixon is a quaker.
It is false that Nixon is a pacifist.

Applications of ACE

- *specifications that we developed*: automated teller machine, Kemmerer's library data base, Schubert's Steamroller, data base integrity constraints, Kowalski's subway regulations etc.
- *natural language interfaces*: model generator EP Tableaux (Munich), FLUX agent/robot control (Dresden), MIT's process query language (Zurich), RuleML (New Brunswick)
- *medicine*: reports, hospital guidelines (Yale)
- *semantic web*: business & policy rules, translation into and from web-languages, protein ontology (EU Network of Excellence REWERSE)
- annotations of web-pages in controlled natural language (Macquarie)

Attempto Web-site

http://attempto.ifi.uzh.ch/site/

- Attempto web-site answers questions you may have concerning ...

Attempto Project
News
People
Tools
Documentation
Publications
Downloads
Talks
Courses
Cooperations
Contact

- here you will soon find the slides of this course

CNL

2009

Workshop on Controlled Natural Language (CNL) 2009

Submission deadline: 14 November 2008
Workshop date: 8-10 June 2009
Location: Marettimo Island, Italy

More information at attempto.ifi.uzh.ch/site/cnl2009/

Appendix