KNOWLEDGE REPRESENTATION AND INFERENCE

CHAPTER 2

cse 352

Lecture Notes (2)

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Requirements for Knowledge Representation Languages

- Representational adequacy:
  It should allow to represent all knowledge that one needs to reason with.

- Inferential Adequacy:
  It should allow new knowledge to be inferred from basic set of facts.

Requirements for Knowledge Representation Languages

- Inferential Efficiency:
  Inferences should be made efficiently.

- Naturalness:
  The language should be reasonably natural and easy to use.

Requirements for Knowledge Representation Languages

- Clear Syntax and Semantics:
  We should clearly **define**
- the language,
- allowable formulas,
- and their meaning

Syntax and Semantics

- Syntax (Symbols):
  Formal Language = Set of Symbols

- Semantics:
  semantics is the assignment of well defined **meaning** to all symbols smbols of the language

Syntax and Semantics

- Example 1:

  Propositional Language Knowledge representation:

  Syntax: propositional language

  p and q represent logical sentences

  $(p \Rightarrow q)$ is a well formed formula of the language

Syntax and Semantics

Classical Propositional Logic Semantics:

- If light goes on, then bring a towel.
- p : light goes on,
  q: bring a towel
- (p ⇒ q)
- p is True or False.
  q is True or False.

⇒	T	F
T	T	F
F	T	T

Syntax and Semantics

- We say:

A is **tautologically true**

- iff A is a propositional tautology
- NOTATION for "A is a propositional tautology " is

$$\models A$$

Propositional Syntax and Semantics

- Example 2
- Syntax: $(p \Rightarrow q)$

  - p: 2+2 = 4
    q: 2+7=3

  - Semantics: $(T \Rightarrow F) = F$

  - Hence, $(p \Rightarrow q)$ is False in this particular case.

Syntax and Semantics
First Order Logic

- Example (Book):

Red(Allison, Car) ≡ Allison's car is red.
(Intended Interpretation)

  - Red – Two argument predicate symbol.
  - Alison – Constant
  - Car – Constant.

$P(C_1, C_2)$

Syntax and Semantics

Book Example

- Question: about the knowledge representation:

    Is Red (as a color) always a 2−argument relation?

  What about “Red (flower)” with intended semantics- Red here is one argument predicate
- But it may be OK in your particular program, if well defined and used consistently –
- PRINCIPLE: Always define your syntax and semantics – It is formal and not intuitive !!!

Syntax and Semantics

Book Example

- We can have two knowledge Representations for "Alison's car is Red."
- Knowledge Representation 1:
  - Red(Allison, Car)
  - Here we have a predicate of the form: $P\ (C_1, C_2)$, i.e., two argument predicate.
  - Pure Logic:
  - Red(x,y) ↔ x has a Red y (intuitive meaning)

Syntax and Semantics
Book Example

- Knowledge Representation 2:
  - Check book, page 10.
  - Red(x) $\leftrightarrow$ x is red. (Different semantics !)
  - **Constant:** Allisons−car
  - Syntax: Red(Allisons−car)
  - Pure Logic: P(C).
    - P is one argument predicate, C is a constant
    - P(x) is one argument predicate.
    - $P_{\underline{r}}$: Red (Intended Interpretation.)

Syntax and Semantics

Book Example

- The following **two knowledge representations** should not appear together !

1. **∃x** Red (x, house)
   There is x, such that Red(x, house) is true under intended interpretation;

   This means some people have a red house.
2. **∃x** Red (x)
   This means some x (object) is Red under intended interpretation

Naturalness

- A **Knowledge Representation language** should allow you to represent adequately complex facts in a clear, precise and natural way.
- Use Intended Semantics (refer back to Block World)
- Some facts are hard to represent in a way that we can also correctly reason with them.

Naturalness

- Example:
  John believes no-one likes brussel sprouts.
  - Believes - ??
  - Syntax: Bel (x,y)
    Semantics: x believes in y
  - What are rules that govern our believe system?
  - Believe Logics, Modal Logics, etc.
  - We are out of first order classical logic.

Clear Syntax and Semantics

SYNTAX ⟷ SEMANTICS

- A precise syntax and semantics are particularly important given that an AI program will be reasoning with the knowledge and drawing new conclusions

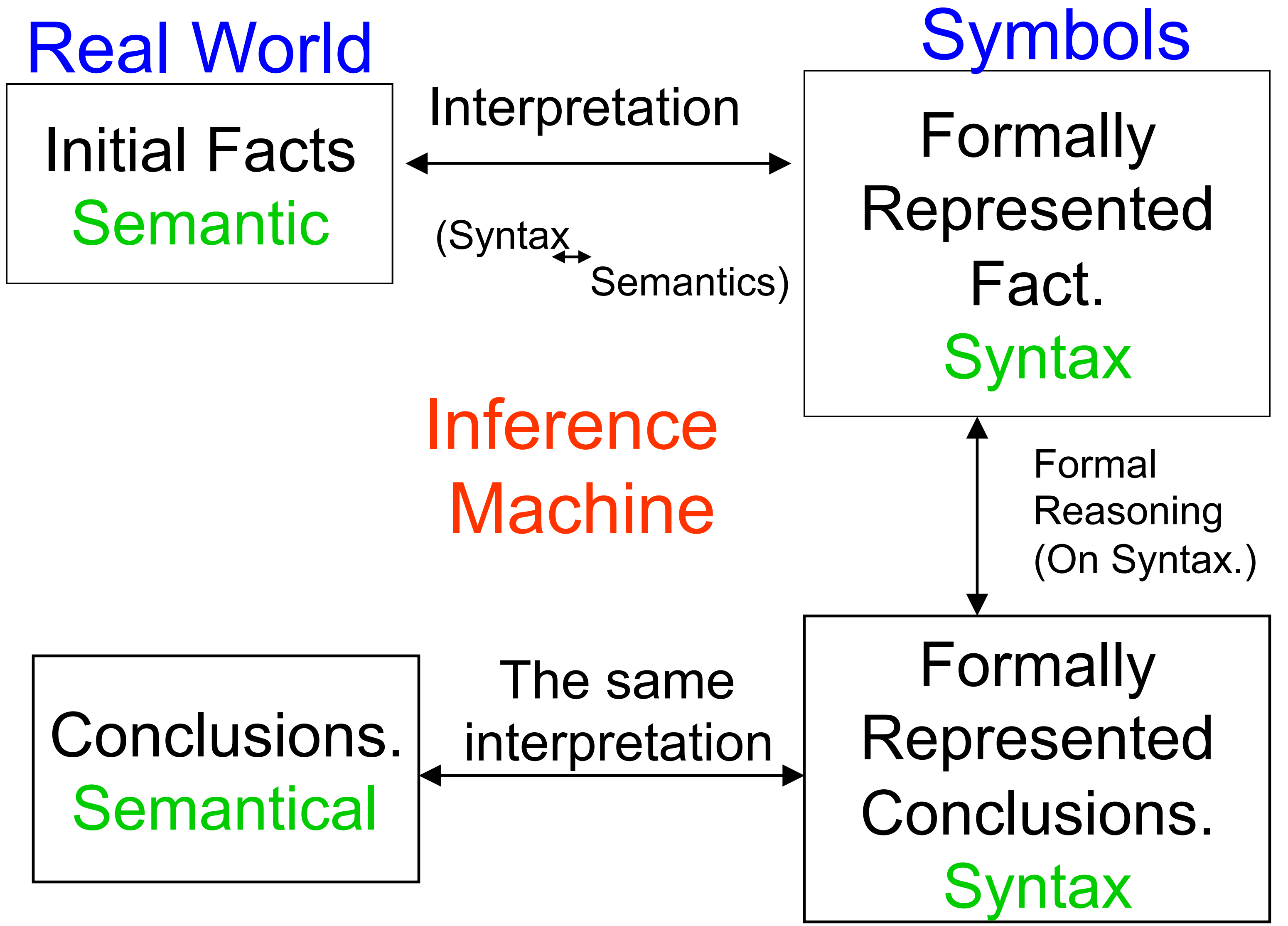
Clear Syntax and Semantics

- Example:
  If system concludes:
  "Interest (Alison, high)"
  we need to know what it means !

  Does it mean:
  - Allison's Mortgage interest is high.
  - I am interested highly in Allison.
  - Or maybe... Allison is interested in high mountains climbing.

  And all this under Intended Interpretation.
  Interest(x,y) iff "x is interested in y" (defined intiitively)

Syntax – Semantics Picture



Inferential Adequacy

- We have to be able to deduce new facts from existing knowledge

- Knowledge Representation Language Must Support Inference

- Point:
  We can't represent explicitly everything that the system might ever need to know; Some things must be left implicit to be deduced when needed.

Inferential Adequacy

- Example:
  Let us say we have Knowledge about a 100 students. It is wasteful to record all facts about all students (in one database)
  - We should be able to deduce that Fred attends (some) lectures from the fact that Fred is a student, etc.
  - Fred cannot be the president of the USA
  - We deduce it from the fact that USA has a president and it is not Fred, etc.

Main Approaches to Knowledge Representation

- Logics:
- Propositional, Predicate, Classical, non-classical
- Frames and Semantic Networks (Nets).
- Rule – Based Systems

Main Approaches to Knowledge Representation

- Logic:
  represents declarative approach and often classical reasoning
- There are many logics:
- Classical logic, non-classical logics: temporal, modal, belief, fuzzy, intuitionistic and many others

Main Approaches to Knowledge Representation

- Frames and Semantic Networks (Nets):
  - Natural way to represent factual knowledge about classes of objects and their properties.
  - Knowledge is represented as a collection of objects and relations.
    The special relations are: Subclass and Instance, and we define the property of Inheritance.

Main Approaches to Knowledge Representation

- Rule – Based Systems:
  - **Procedural aspects** of our knowledge are stressed more than the declarative ones.
  - Condition – Action rules are widely used in Expert Systems
  - A Rule – Based language provides algorithms for reasoning with such rules

Main Approaches to Knowledge Representation

- Rule – Based Systems :
- Rule – based systems are also called
- Production Systems.

  - **They were first introduced by**
  Emil Post in 1944

  - More modern form is due to A. Newell & H.A. Simon (1972) and was developed first **for psychological modeling**