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 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
- \( (p \Rightarrow q) \)
- \( p \) is True or False.
- \( q \) is True or False.


\[
\begin{array}{c|c|c}
\Rightarrow & T & F \\
\hline
T & T & F \\
F & T & T \\
\end{array}
\]
Syntax and Semantics

• We say:

\[ A \text{ is tautologically true} \]

• 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):

  \[
  \text{Red( Allison, Car) } \equiv \text{ Allison’s car is red.}
  \]
  (Intended Interpretation)

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

\[
\text{P(C}_1, \text{ C}_2)\]
• **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 (C₁, C₂), 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:
  ▪ $\text{Red}(x) \leftrightarrow x$ is red. (Different semantics!)
  ▪ **Constant**: Allisons–car
  ▪ **Syntax**: $\text{Red}(\text{Allisons–car})$
  ▪ **Pure Logic**: $P(C)$.
    ▪ $P$ is one argument predicate, $C$ is a constant
    ▪ $P(x)$ is one argument predicate.
    ▪ $P_{\text{r}} : \text{Red}$  (Intended Interpretation.)
Syntax and Semantics

Book Example

• The following two knowledge representations should not appear together!

1. $\exists x \text{ Red}(x, \text{ house})$
   There is $x$, such that $\text{Red}(x, \text{ house})$ is true under intended interpretation;
   This means some people have a red house.

2. $\exists x \text{ Red}(x)$
   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

• 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.

\[ \text{Interest}(x,y) \iff \text{“}x\text{ is interested in } y\text{”} \] (defined intiitively)
Syntax – Semantics Picture

Real World
Initial Facts
Semantic

Inference Machine
Conclusions. Semantical

Symbols
Formally Represented Fact. Syntax

Formally Represented Conclusions. Syntax

Interpretation (Syntax Semantics)
The same interpretation

Formal Reasoning (On Syntax.)
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