Knowledge as structured and organized in terms of what the knowledge is about, the objects of knowledge.

Objects with parts, constraints

Frame (Minsky 1975)

Frames

- Individual Frames – to represent single objects
- Generic Frames – to represent categories of objects.
- slots, fillers

\[
\text{Frames} - \text{Example}
\]

\[
\begin{align*}
\text{CanadianCity} & : \text{IS-A City} \\
& : \text{Province CanadianProvince} \\
& : \text{County canada} \\
& : \text{Population 4.5M}
\end{align*}
\]

\[
\begin{align*}
\text{Table} & : \text{Clearance [IF-NEEDED ComputeClearanceFromLeg} \\
& \ldots \\
\text{Lecture} & : \text{DayOfWeek WeekDay} \\
& : \text{Date [IF-ADDED ComputeDayOfWeek]} \\
& \ldots
\end{align*}
\]

Individual Frames: Example

\[
\begin{align*}
\text{tripLeg123} & : \text{INSTANCE-OF TripLeg} \\
& : \text{Destination toronto} \\
\end{align*}
\]

\[
\begin{align*}
\text{toronto} & : \text{INSTANCE-OF CanadianCity} \\
& : \text{Province ontario} \\
& : \text{Population 4.5M}
\end{align*}
\]
Inheritance

(Table
  <:Clearance [IF-NEEDED ComputeClearanceFromLeg...

(CoffeeTable
  <:IS-A Table>...

(MahoganyCoffeeTable
  <:IS-A CoffeeTable>..

Inheritance (defaults)

(Elephant
  <:IS-A Mammal>
  <:EarSize large>
  <:Color gray>...

(raja
  <:INSTANCE-OF Elephant>
  <:EarSize small>..

(RoyalElephant
  <:IS-A Elephant>
  <:Color white>..

(cl Clyde
  <:INSTANCE-OF RoyalElephant>..

Reasoning with Frames

1. a user or external system declares that an object exists, thereby instantiating some generic frame;
2. any slot fillers that are not provided explicitly, but can be inherited, are computed;
3. for each slot with a filler, any IF-ADDED procedure that can be inherited is run, possibly causing new slots to be filled, or new frames to be instantiated, and the cycle repeats.

Description Logics

- Objects fall into classes.
- Some classes are more general than others.
- Objects have parts.
- concepts, roles constants
A Description Language DL

Logical Symbols

1. **punctuation**: “[”, “]”, “(”, “);”
2. **positive integers**: 1, 2, 3, etc.
3. **concept-forming operators**: “ALL”, “EXISTS”, “FILLS”, “AND”;
4. **connectives**: “$\subseteq$”, “$\in$”, “$\rightarrow$”.

Non-Logical Symbols

1. **atomic concepts**: written in capitalized mixed case, e.g., *Person*, *WhiteWine*, *FatherOfOnlyDaughters*; and a special atomic concept *Thing*.
2. **roles**: written like atomic concepts, but preceded by “:”, e.g., :Child, :Height, :Employer, :Arm.
3. **constants**: written in uncapitalized mixed case, e.g. *table13*, *maryAnnJones*.

Syntactic expressions

There are four types of syntactic expressions:

1. **constants**
2. **roles**
3. **concepts**
4. **sentences**

Concepts

The set of concepts of $\mathcal{DL}$ is the least set satisfying:
- every atomic concept is a concept;
- if $r$ is a role and $d$ is a concept, then $[\text{ALL } r \ d]$ is a concept;
- if $r$ is a role and $n$ is a positive integer, then $[\text{EXISTS } n \ r]$ is a concept;
- if $r$ is a role and $c$ is a constant then, $[\text{FILLS } r \ c]$ is a concept;
- if $d_1 \ldots d_n$ are concepts, then $[\text{AND } d_1 \ldots d_n]$ is a concept;
Sentences

- if \( d_1 \) and \( d_2 \) are concepts, then \([d_1 \sqsubseteq d_2]\) is a sentence;
- if \( d_1 \) and \( d_2 \) are concepts, then \([d_1 = d_2]\) is a sentence;
- if \( c \) is a constant and \( d \) a concept, then \([c \rightarrow d]\) is a sentence.

Examples: Concepts

\([\text{EXISTS } n r]\)

\([\text{EXISTS } 1 : \text{Child}]\)

\([\text{FILLS } r c]\)

\([\text{EXISTS } : \text{Cousin vinny}]\)

\([\text{ALL } r d]\)

\([\text{ALL } : \text{Employee UnionMember}]\)

Examples (cont)

\([\text{ANDwine} \quad \text{FILLS} : \text{Color red}]\)

\([\text{EXISTS } 2 : \text{GrapeType}]\)

Examples: Sentences

\((d_1 \sqsubseteq d_2)\)

\((\text{Surgeon} \sqsubseteq \text{Doctor})\)

\((d_1 = d_2)\)

\((d_1 \rightarrow d_2)\)

\(\text{ProgressiveCompany} =\)

\([\text{ANDCompany} \quad \text{EXISTS } 7 : \text{Director}]\)

\([\text{ALL } 7 : \text{Manager[AND Woman}}\)

\([\text{FILLS} : \text{Degree phD}]\]

\([\text{FILLS} : \text{MinSalary $24.00/hour}]\]
Semantics

An interpretation $\mathfrak{I}$ for DL is a pair

$$\langle D, I \rangle$$

where $D$ is any set of objects called the domain of the interpretation

and

$I$ is a mapping called the interpretation mapping from the non-logical symbols of DL to elements and relations over $D$.

Extending $I$

- $I[\text{thing}]$
- $I[\text{ALL } r \ d]$
- $I[\text{EXISTS } n \ r]$
- $I[\text{FILLS } r \ c]$
- $I[\text{AND} \ d_1 \ldots d_n]$

Truth in an Interpretation

Given an interpretation $\mathfrak{I}$, we say that $\alpha$ is true in $\mathfrak{I}$, or $\mathfrak{I} \models \alpha$ according to the following rules.

1. $\mathfrak{I} \models (c \rightarrow d)$ iff $I[c] \subseteq I[d]$;
2. $\mathfrak{I} \models (d \sqsubseteq d')$ iff $I[d] \subseteq I[d']$;
3. $\mathfrak{I} \models (d \doteq d')$ iff $I[d] = I[d']$;

Assuming that $d$ and $d'$ are concepts, and $c$ is a constant.