1. SEARCH
2. MACHINE LEARNING
3. LOGIC - INFERENCE
A search problem

It is represented in a semi-structured manner.

Represent components:
1. goal
2. actions (transition model)
3. initial state
4. cost model

Any lack of detail represents knowledge representation and reasoning algorithm.

1. time complexity
2. space complexity (correct?)
3. completeness
4. optimality
something to learn

machine learning

learn something

down the key here

- neural network (representation)
- algorithms
- version spaces
- decision trees
- clusters
logical reasoning

logic

propositional predicate


T/F
T/F

if this then that
A → B

(a ∨ b ∨ c) ∧ (a ∨ d ∨ e) ∧ (¬ . . . )

conjugate normal form

disjunctive normal form

(a ∧ b ∧ ¬c) ∨ ( ) ∨ ( )

p → q

"statement" that has a truth value

a: snow white eats an apple
b: snow white gets poisoned
new facts through inference algorithm for reasoning

facts and rules about the world

proposition: $p, q, r$

- $p \land q$ and
- $p \lor q$ or
- $p \rightarrow q$ implies
- $p \equiv q$ defines

common logic operators:

<table>
<thead>
<tr>
<th>$p$</th>
<th>$q$</th>
<th>$p \land q$</th>
<th>$p \lor q$</th>
<th>$p \rightarrow q$</th>
<th>$p \equiv q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

$\neg r$ = not

$(p \rightarrow q)$

$(q \rightarrow p)$
model: state of the world

sentence: $\varphi$
$p \Rightarrow \varphi$
$(p \lor \varphi) \land \Gamma$ well-formed formula

model of a sentence $\models$ all the models where the sentence is true.

$\operatorname{model}(\alpha) = \begin{cases} 
p = t, \varphi = t; \\
p = f, \varphi = t; \\
p = f, \varphi = f \end{cases}$

model: state of the world
truth value of all the propositions that are defined.
Example

s: sunny spring day
h: Nilufar is happy

\[ s \rightarrow h \]
\[ s \]

prove: h

\[
\begin{array}{ccc}
0 & 0 & 1 \\
1 & 1 & 0 \\
1 & 0 & 1 \\
0 & 0 & 0 \\
\end{array}
\]

models of the KB

A sentence can be proven if in all models of the KB the statement we are trying to prove is also true.

models (KB) \subseteq models (x)

Is it true that in all rows where the KB is true, h is true?
I look at all models where the rows.

The KB is true if my sentence $\alpha$ is also true in all of these rows, then I say $\alpha$ is proven (inferred).

\[ \text{entails} \]

$KB \models \alpha \quad \text{if} \quad KB \models \alpha$ \quad $KB \models \alpha$

Did this correct?

$KB$: sentences in propositional logic
$p$
$q$
$p \rightarrow q$
$q \leftrightarrow s$

$\alpha$: to prove $\alpha$
$q \rightarrow t$
\[ p_1 \rightarrow p_2 \rightarrow p_3 \rightarrow p_4 \rightarrow p_5 \rightarrow p_6 \]

\[ p_2 \rightarrow p_3 \rightarrow p_4 \leftrightarrow p_4 \rightarrow p_5 \rightarrow p_6 \]

\[ p_3 \rightarrow p_4 \rightarrow p_2 \rightarrow p_3 \rightarrow p_4 \rightarrow p_5 \rightarrow p_6 \]

\[ p_1 \rightarrow p_2 \land p_3 \rightarrow p_2 \land p_3 \]

\[ p_2 \checkmark \]

\[ p_3 \checkmark \]

\[ \text{correct } \checkmark \]

\[ \text{for model checking } \checkmark \]

\[ \text{time and space exhaustive search} \]
n propositions
2^n

250

time 2^n

space constant = 1 row of information.

example

\[ p \rightarrow q \]
\[ lA \rightarrow p \]
\[ b \land l \rightarrow m \]
\[ a \land p \rightarrow l \]
\[ a \land s \rightarrow l \]

\[ a \quad b \]

forward-chaining

time complexity

2^n - 250

\[ a, b, p, l, m, q \]

2^6 = 64

m = facts

O(m)