Quiz 3 review by Jenny Zeng

Propositional Logic

logical Agents

basic concepts:

1. **Propositional logic**: concrete statements that are either true or false. e.g. John is married to Sue.
2. **Predicate logic (first order logic/ first order predicate calculus)**: allows statements to contain variables, functions, and quantifiers. e.g. For all X, Y: If X is married to Y then Y is married to X.
3. **Probability:** statements that are possibly true; the chance I win the lottery?
4. **Fuzzy logic:** vague statements; paint is slightly grey; sky is very cloudy.
5. **Modal logic:** is a class of various logics that introduce modalities:
    - **Temporal logic:** statements about time; John was a student at UCI for four years
    - **Belief and knowledge**: Mary knows that john is married to Sue
    - **Possibility and Necessity:** what might happen(possibility) and must happen (nacessity);
    - **Obligation and Permission:** It is obligatory taht students study for their tests; it is permissible that I go fishing when I am on vacation.
6. **Induction:** Reason from facts to the general law.
7. **Abduction:** Reason from facts to the best explanation.
8. **Analogy:** Reason that a new situation is like an old one.
9. **Schematic perspective:** If KB is true in the real world, then any sentence α entailed by KB is also true in the real world.

important concepts:

1. **Logics:** are formal languages for represneting information such as conclusions can be drawn from formal inference patterns.
2. **Syntax:** Specifies all the sentences in a language that are well formed.
3. **Semantics**: Defines truth of each sentence with respect to each possible world.
4. **Entailment:** The idea that a sentence follows logically from other sentneces.
5. **inference**: deriving sentences from other sentences
6. **model:** Possible world that assigns TRUE or FALSE to each proposition.
7. **soundness:** derivations produce only entailed sentences

8. **KB**: knowledge base - a set of sentences or facts
9. **valid**: sentence is true in every model (a tautology)
10. **satisfiable:** A sentence is satisfiable if it is true in some model
11. **unsatisfiable:** A sentence is unsatisfiable if it is false in all model.

logical equivalence

Two sentences are logically equivalent iff they are true in same models: α ≡ ß iff α ⊨ β and β ⊨ α

You need to know these !

$$
\begin{aligned}
(\alpha \wedge \beta) &\equiv (\beta \wedge \alpha) && \text{commutativity of } \wedge \\
(\alpha \vee \beta) &\equiv (\beta \vee \alpha) && \text{commutativity of } \vee \\
((\alpha \wedge \beta) \wedge \gamma) &\equiv (\alpha \wedge (\beta \wedge \gamma)) && \text{associativity of } \wedge \\
((\alpha \vee \beta) \vee \gamma) &\equiv (\alpha \vee (\beta \vee \gamma)) && \text{associativity of } \vee \\
\neg(\neg\alpha) &\equiv \alpha && \text{double-negation elimination} \\
(\alpha \Rightarrow \beta) &\equiv (\neg\beta \Rightarrow \neg\alpha) && \text{contraposition} \\
(\alpha \Rightarrow \beta) &\equiv (\neg\alpha \vee \beta) && \text{implication elimination} \\
(\alpha \Leftrightarrow \beta) &\equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)) && \text{biconditional elimination} \\
\neg(\alpha \wedge \beta) &\equiv (\neg\alpha \vee \neg\beta) && \text{de Morgan} \\
\neg(\alpha \vee \beta) &\equiv (\neg\alpha \wedge \neg\beta) && \text{de Morgan} \\
(\alpha \wedge (\beta \vee \gamma)) &\equiv ((\alpha \wedge \beta) \vee (\alpha \wedge \gamma)) && \text{distributivity of } \wedge \text{ over } \vee \\
(\alpha \vee (\beta \wedge \gamma)) &\equiv ((\alpha \vee \beta) \wedge (\alpha \vee \gamma)) && \text{distributivity of } \vee \text{ over } \wedge
\end{aligned}
$$

truth table

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$	$P \Leftrightarrow Q$
$false$	$false$	$true$	$false$	$false$	$true$	$true$
$false$	$true$	$true$	$false$	$true$	$true$	$false$
$true$	$false$	$false$	$false$	$true$	$false$	$false$
$true$	$true$	$false$	$true$	$true$	$true$	$true$

Methods of Proof

1. **Sound:** An inference procedure that derives only entailed sentences.
2. **Complete:** An inference procedure that derives all entailed sentences.
3. **Propositional Symbol:** Stands for a proposition taht can be true or false.
4. **Proof:** Chain of inference rule conclusions leading to a desired sentence.
5. **Conjunctive Normal Form:** Describes a sentence that is true in some model.

Knowledge engineering process

1. Identify the task.

2. Assemble the relevant knowledge.
3. Decide on a vocabulary of predicates, functions, and constants.
4. Encode general knowledge about the domain.
5. Encode a description of the specific problem instance.
6. Pose queries to the inference procedure and get answers.
7. Debug the knowledge base.

First-order Logic Syntax

Syntax of FOL:

- A **Predicate** is a list of m-tuples making the predicate true.
  - E.g., PrimeFactorOf = {<2,4>, <2,6>, <3,6>, <2,8>, <3,9>, …}
- A **Property** lists the m-tuples that have the property.
  - E.g., IsRed = { < Ball-5 >, < Toy-7 >, < Car-11 > }
- A **Function** CAN BE represented as an m-ary relation
  – the first (m-1) objects are the arguments and the mth is the value.
- An **Object** CAN BE represented as a function of zero arguments that returns the object.
- **Term** = logical expression that refers to an object
  - **Constant Symbols** stand for (or name) objects
  - **Function Symbols** map tuples of objects to an object
- **Atomic Sentences** state facts (logical truth values).

possible quiz questions

1. All persons are mortal.
   "All persons are mortal."
   [Use: Person(x), Mortal (x)]

   $\forall x\ \text{Person}(x) \Rightarrow \text{Mortal}(x)$
   $\forall x\ \neg\text{Person}(x) \vee \text{Mortal}(x)$
   Common Mistakes:
   $\forall x\ \text{Person}(x) \wedge \text{Mortal}(x)$

2. Fifi has a sister who is a cat.
   "Fifi has a sister who is a cat."
   [Use: Sister(Fifi, x), Cat(x)]

   $\exists x\ \text{Sister}(\text{Fifi}, x) \wedge \text{Cat}(x)$
   Common Mistakes:
   $\exists x\ \text{Sister}(\text{Fifi}, x) \Rightarrow \text{Cat}(x)$

3. For every food, there is a person who eats that food.

"For every food, there is a person who eats that food."
[Use: Food(x), Person(y), Eats(y, x)]

$\forall x\ \exists y$ Food(x) $\Rightarrow$ [Person(y) $\wedge$ Eats(y, x)]
$\forall x$ Food(x) $\Rightarrow\ \exists y$ [Person(y) $\wedge$ Eats(y, x)]
$\forall x\ \exists y\ \neg$Food(x) $\vee$ [Person(y) $\wedge$ Eats(y, x)]
$\forall x\ \exists y$ [$\neg$Food(x) $\vee$ Person(y)] $\wedge$ [$\neg$ Food(x) $\vee$ Eats(y, x)]
$\forall x\ \exists y$ [Food(x) $\Rightarrow$ Person(y)] $\wedge$ [Food(x) $\Rightarrow$ Eats(y, x)]

Common Mistakes:
$\forall x\ \exists y$ [Food(x) $\wedge$ Person(y)] $\Rightarrow$ Eats(y, x)
$\forall x\ \exists y$ Food(x) $\wedge$ Person(y) $\wedge$ Eats(y, x)

4. every person eats every food.

"Every person eats every food."
[Use: Person (x), Food (y), Eats(x, y)]

$\forall x\ \forall y$ [Person(x) $\wedge$ Food(y)] $\Rightarrow$ Eats(x, y)
$\forall x\ \forall y\ \neg$Person(x) $\vee\ \neg$Food(y) $\vee$ Eats(x, y)
$\forall x\ \forall y$ Person(x) $\Rightarrow$ [Food(y) $\Rightarrow$ Eats(x, y)]
$\forall x\ \forall y$ Person(x) $\Rightarrow$ [$\neg$Food(y) $\vee$ Eats(x, y)]
$\forall x\ \forall y\ \neg$Person(x) $\vee$ [Food(y) $\Rightarrow$ Eats(x, y)]

Common Mistakes:
$\forall x\ \forall y$ Person(x) $\Rightarrow$ [Food(y) $\wedge$ Eats(x, y)]
$\forall x\ \forall y$ Person(x) $\wedge$ Food(y) $\wedge$ Eats(x, y)

5. all greedy kings are evil.

"All greedy kings are evil."
[Use: King(x), Greedy(x), Evil(x)]

$\forall x$ [Greedy(x) $\wedge$ King(x)] $\Rightarrow$ Evil(x)
$\forall x\ \neg$Greedy(x) $\vee\ \neg$King(x) $\vee$ Evil(x)
$\forall x$ Greedy(x) $\Rightarrow$ [King(x) $\Rightarrow$ Evil(x)]

Common Mistakes:
$\forall x$ Greedy(x) $\wedge$ King(x) $\wedge$ Evil(x)

6. everyone has a favorite food.

"Everyone has a favorite food."
[Use: Person(x), Food(y), Favorite(y, x)]

$\forall x\ \exists y$ Person(x) $\Rightarrow$ [Food(y) $\wedge$ Favorite(y, x)]
$\forall x$ Person(x) $\Rightarrow\ \exists y$ [Food(y) $\wedge$ Favorite(y, x)]
$\forall x\ \exists y\ \neg$Person(x) $\vee$ [Food(y) $\wedge$ Favorite(y, x)]
$\forall x\ \exists y$ [$\neg$Person(x) $\vee$ Food(y)] $\wedge$ [$\neg$Person(x) $\vee$ Favorite(y, x)]
$\forall x\ \exists y$ [Person(x) $\Rightarrow$ Food(y)] $\wedge$ [Person(x) $\Rightarrow$ Favorite(y, x)]

Common Mistakes:
$\forall x\ \exists y$ [Person(x) $\wedge$ Food(y)] $\Rightarrow$ Favorite(y, x)
$\forall x\ \exists y$ Person(x) $\wedge$ Food(y) $\wedge$ Favorite(y, x)

7. There is someone at UCI who is smart.

"There is someone at UCI who is smart."

[Use: Person(x), At(x, UCI), Smart(x)]

$\exists x$ Person(x) $\wedge$ At(x, UCI) $\wedge$ Smart(x)

Common Mistakes:

$\exists x$ [Person(x) $\wedge$ At(x, UCI)] $\Rightarrow$ Smart(x)

8. Every one at UCI is smart.

"Everyone at UCI is smart."

[Use: Person(x), At(x, UCI), Smart(x)]

$\forall x$ [Person(x) $\wedge$ At(x, UCI)] $\Rightarrow$ Smart(x)

$\forall x$ $\neg$[Person(x) $\wedge$ At(x, UCI)] $\vee$ Smart(x)

$\forall x$ $\neg$Person(x) $\vee$ $\neg$At(x, UCI) $\vee$ Smart(x)

Common Mistakes:

$\forall x$ Person(x) $\wedge$ At(x, UCI) $\wedge$ Smart(x)

$\forall x$ Person(x) $\Rightarrow$ [At(x, UCI) $\wedge$ Smart(x)]

9. Every person eats some food.

"Every person eats some food."

[Use: Person (x), Food (y), Eats(x, y)]

$\forall x$ $\exists y$ Person(x) $\Rightarrow$ [Food(y) $\wedge$ Eats(x, y)]

$\forall x$ Person(x) $\Rightarrow$ $\exists y$ [Food(y) $\wedge$ Eats(x, y)]

$\forall x$ $\exists y$ $\neg$Person(x) $\vee$ [Food(y) $\wedge$ Eats(x, y)]

$\forall x$ $\exists y$ [$\neg$Person(x) $\vee$ Food(y)] $\wedge$ [$\neg$Person(x) $\vee$ Eats(x, y)]

Common Mistakes:

$\forall x$ $\exists y$ [Person(x) $\wedge$ Food(y)] $\Rightarrow$ Eats(x, y)

$\forall x$ $\exists y$ Person(x) $\wedge$ Food(y) $\wedge$ Eats(x, y)

10. some person eats some food.

"Some person eats some food."

[Use: Person (x), Food (y), Eats(x, y)]

$\exists x$ $\exists y$ Person(x) $\wedge$ Food(y) $\wedge$ Eats(x, y)

Common Mistakes:

$\exists x$ $\exists y$ [Person(x) $\wedge$ Food(y)] $\Rightarrow$ Eats(x, y)