Exam 2 Review

Knowledge Representation

- **Production (Rule-Based) Systems**
  - System components: WM, rule base, inference engine (rule interpreter)
  - Inference procedure
    - Cycle of three phases: match, conflict-resolution, act/fire
    - Forward and backward inference
  - Conflict resolution
    - conflict set
    - conflict resolution policies (refraction, specificity, recency, priority/rule-ordering)
  - Advantages
    - **Simplicity** (for both language and inference)
    - Efficiency
    - Modularity (easy for KB maintenance)
    - Natural for many application domains
  - Disadvantages
    - **No clearly defined semantics** (based on informal understanding)
    - Incomplete inference procedure
    - Unpredictable side effects of ordering of rule applications
    - Less expressive (may not be suitable for some applications)

- **Structured representation**
  - Semantic (associative) networks
    - Labeled nodes: objects, classes, concepts
    - Labeled directed links: relations (associations) between nodes
    - reification
    - Reasoning about associations (marker passing and spreading activation)
  - ISA hierarchy and property inheritance
    - Super/subclass and instance/class relation
    - **Inference by inheritance**
    - **Multiple inheritance** (from different parents, from ancestors of different distances)
    - Exceptions in inheritance/default reasoning
  - Frame Systems
    - Definition (stereotypical views of the world; record like structure)
    - Slots, their values and facets

- **Default reasoning**
  - **Definition** (inference is drawn in the absence of info to the contrary) and examples
  - Default reasoning is **non-monotonic**, and it totally undecidable
  - How rule-based systems and semantic networks (and frame systems) deal with simple default reasoning

- **Abduction**
  - Definition
  - **Difference between abduction, deduction, and induction**

- Characteristics of abductive inference
  - Inference results are hypotheses, not theorems (may be false)
  - There may be multiple plausible hypotheses
  - Reasoning is often a hypothesize-and-test cycle
  - Reasoning is non-monotonic
  - Inherently uncertain

Planning

- **Situation calculus planning**
  - Reasoning about change in the world
  - Representing states and state changes by actions
  - Planning by theorem proving (expensive)
- **STRIPS planning**
  - State, goal: using ground literals
  - Actions/operators: add-list and delete-list
  - Simple STRIP planning (assuming goals are independent)
  - Limitations (Sussman's anomaly) because subgoals are satisfied independently
- **Partial order planner** (POP)
  - Difference between total order (linear) and partial order (non-linear) planning
  - Least commitment principle
  - Causal links and ordering constraints
  - A complete POP
  - Linearizing a partial plan

Uncertainty and Probabilistic Reasoning

- Simple Bayesian approach to evidential/diagnostic reasoning
  - Bayes' theorem
  - Conditional independence and single fault assumptions
  - Computing posterior probability and relative likelihood of a hypothesis, given some evidence
  - Limitation
    - Assumptions unreasonable for many problems
    - Not suitable for multi-fault problems
    - Can not represent causal chaining
- **Bayesian networks (BN)**
  - Definition of BN (DAG and CPT).

    $\boldsymbol{P(x_i \mid \pi_i)}$ where $\boldsymbol{\pi_i}$ is the set of all parent nodes of $\boldsymbol{x_i}$
  - **Conditional independence assumption**
    - $P(x_i \mid \pi_i, q) = P(x_i \mid \pi_i)$
    - d-separation
    - Markov blanket

- **Computing joint probability distribution from CPT: chain rule**
- Inference
  - NP-hard
  - Exact methods (**enumeration**, ideas of variable elimination, junction tree and belief propagation)
  - Approximate methods (stochastic sampling, MCMC, loopy propagation)
- BN of noise-or gate (advantages and limitations)
- Learning BN from case data (difficulty in learning the DAG)

- **Fuzzy set theory (for representing vague linguistic terms)**
  - **Difference between fuzzy sets and ordinary sets**
  - Fuzzy membership functions
  - Rules for fuzzy logic connectives
  - Problems with fuzzy logic (comparing with probability theory)

- **Decision making under uncertainty**
  - Actions, uncertain outcomes, and utility
  - **Expected utility**
  - **Maximum expected utility (MEU) principle**
    $EU(\alpha \mid E) = \max_A \sum_i U(Result_i(A))\, p(Result_i(A) \mid E, Do(A))$
  - Decision network (influence diagram)
    - Chance nodes, decision nodes, and utility nodes
    - Value of perfect information (VPI): definition, meaning, how to compute
      $VPI(X) = (\sum_k p(x_k \mid E)\, (EU(\alpha_{xk} \mid x_k, E)) \; - EU(\alpha \mid x_k, E))$

Learning

- **Supervised, unsupervised, and reinforcement learning**

- **Decision tree learning**
  - Decision tree (nodes and arcs)
  - **Information gain** (definition and how to use it to construct a decision tree)
    $Info(T) = I(P) = -\sum_i pi*\log(pi)$; $Info(X,T) = \Sigma|T_i|/|T| * Info(T_i)$
  - **Overfitting problem and cross-validation**
  - Generating rules from decision tree
  - Limitations of decision tree learning

- **Neural Networks**
  - Comparisons between Von Neumann machine and human brain and artificial neural networks
  - Perceptron: the network, the learning rule, and the limitation (**linear separable problems**)
  - Feed forward networks: hidden nodes of non-linear functions, learning rule (**gradient descent**), what does error back propagation mean?
  - Advantages and limitations

- **Support vector machine (SVM)**
  - Basic ideas
    - **Maximum margin** classifier to increase its robustness and generalization power

    - What are support vectors
    - Maximum margin can be computed by quadratic programming (QP)
- Overcome linear separability problem by converting the problem into a higher dimension space
    - converting the problem into a higher dimension feature space
    - **kernel functions** help the dimensionality explosion in QP

Note: materials covered in the class but not listed in this document will not be tested in Exam 2.