Knowledge Representation and Reasoning

Learning Sets of Rules and Analytical Learning

Learning Sets of Rules

- What is Inductive Learning (ILM) ?
- What is the concept of Analytical Learning ?
- What is Explanation-Based Learning (EBL) ?
- When do we use each one of them ?
- How can the two be combined ?
- Which one is more human-like AI ?

IF-THEN rules

- IF-THEN rules model exactly our own prior knowledge and reasoning at high-level
- In generalized form they use variables, like the Predicate Calculus does
- Most common case: first-order Horn clauses, used in Inductive Logic Programming (ILP)
- Algorithms are necessary to implement the induction process (resolution in PROLOG)

Induction algorithms

- Sequential Covering Algorithms:
  - A “Learn-One-Rule” subroutine applies one rule at a time, each limiting the available samples/atoms that satisfy the current conditions enforced by these rules
- General-to-Specific Beam Search (CN2):
  - Works like the tree-search algorithm, using depth-first tree organization and extending the most promising candidate
- Simultaneous Covering Algorithms (ID3):
  - Search simultaneously all the alternatives than can be created by applying any one of the available attributes
- Choice between CN2-like or ID3-like systems is problem-dependent and not exclusive

FOIL algorithm

- First-order Horn clauses are a powerful and simple way to describe general rules
- FOIL (Quinlan, 1990): uses a simple version of Horn clauses and works like the sequential covering algorithms
- FOIL examples: learn Quicksort and Chess by a large set of examples
- In practice, algorithms like FOIL implement deduction by generalizing from examples

Note: FOIL = First-Order Induction Learner (algorithm)

Inductive Learning Methods

- Decision Tree Learning (DTL)
- Artificial Neural Networks (ANN)
- Inductive Logic Programming (ILP)
- Genetic Programming (GP)
- ...

➢ They are all based on statistical generalization and reasoning

Analytical Learning

- Inductive learning methods (ANN, DTL) are based on “generalization by examples” algorithms
- Analytical learning uses **prior knowledge** and deductive reasoning to “augment” information
- Explanation-Based Learning (EBL): prior knowledge is used to analyze/explain how observed training examples satisfy the “target” concept.
- Generalization here is based on logical rather than statistical reasoning.

Explanation-Based Learning

- Prior knowledge (generic) may be included for "explaining" the examples
- In this case, the "complexity" of the hypotheses (input) space can be drastically reduced
- Alternatively, much fewer examples are needed
- Example (chess):
  - concept: "black looses Queen in one move"
  - statistical learning requires all possible pieces setup
  - explanation-based learning generalizes from simple examples
  - result: "black losses Queen if King is in check position"

Explanation-Based Learning

- Basic limitation of EBL: information and assertions by the learner are assumed to be 100% correct!
- If not, then more weight must be assigned to statistical learning (ILM) to avoid misleading results

- PROLOG-EBG: Explanation-based generalization
- Translates new positive examples to generalized hypotheses that cover the entire training set
- Uses Horn clauses as attribute-value pairs

Comparison of ILM and EBL

LEARNING	Inductive (ILM)	Analytical (EBL)
Goal:	Hypothesis fits the data (examples)	Hypothesis fits domain theory
Justification:	Statistical inference	Deductive inference
Advantages:	Requires little prior knowledge	Learns from scarce data
Pitfalls:	Scarce data, incorrect bias	Imperfect domain theory, uncertainty

Combining ILM and EBL

Use prior knowledge to:

- derive an initial hypothesis from which to begin the search (example: KBANN)
- alter the objective of the hypothesis search space (example: EBNN)
- alter the available search steps by applying multiple “revisions” (example: FOCL)

Food for thought

- When ILM is better than EBL ?
- When EBL is better than ILM ?
- Which one should be used in designing a computer chess player ?
- Which one should be used in designing a computer medical assistant ?
- Which one is more similar to the human way of thinking and problem-solving ability ?

P.C. – Readings

- Tom Mitchell, “Machine Learning”,McGrawHill, 1997. [see: ch.10, ch.11, ch.12]
- S. J. Russell, P. Norvig, “Artificial Intelligence: A Modern Approach”, 2nd/Ed, Prentice Hall, 2002.