Mathematical and Machine Learning approaches to Context

Good news: Machine Learning has some techniques that are relevant to dealing with the context problem

Bad news:

- Vocabularies are specialized and difficult to understand
- Tools have very specific strengths and weaknesses, so be careful when applying techniques
References for Machine Learning

Elements of Machine Learning
  Pat Langely, MorganKauffman, 1996

Machine Learning

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Machine Learning is often described as Classification

Classification Problem:

• Given a “training sequence” of examples, figure out if a new example belongs to the set or not

• Supervised vs. Unsupervised learning

Other problems can be “reduced to classification”, but it’s a pain
Learning problems for context-aware applications

- Action Description
- Data Description
- Sequence Prediction
- Inferring Preferences
- Feature Selection
Traditional mathematical inference techniques

First-order logical inference almost guaranteed to fail in problems where context is important

Deduction insists on sound inference

Contextually based inference formulated as a problem of induction, not deduction

Induction from specific to general not sound

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Watch out for hidden assumptions in machine learning

Everything appears at once. Incremental
Batch vs. Interactive
Pretending the user doesn’t exist
Generalization Lattice
Version Spaces

Lattice of hypotheses ordered by generalization

Each step proceeds by

• Making the Most Specific hypothesis a little more general

• Making the Most General hypothesis a little more specific

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Version Spaces
Case-Based Reasoning

Index specific examples and solutions in a case base

When you get a new example:
  • Retrieve the closest case
  • Modify the solution to fit the current case

Works by delaying generalization
Explanation-Based Generalization

Present an example, a generalization, and show the example satisfies the generalization

- New examples can make analogies to the old explanation

Works by recording dependencies, and propagating generalizations through dependencies
Learning by Analogy

Find successful previous experience

Map roles in past examples to new example

Gentner; Structure-Mapping
Sequence prediction

Given examples of a sequence, what’s the next element?

1, 4, 9, 16, 25, ...

4, 14, 34, 42, 59, 72, 96, 125,...

Loop detection
Grammar induction

• Sequitur - Neville-Manning, Maulsby, Witten
Approaches that use large numbers of examples

- Genetic Algorithms
  - Analogy to Evolutionary Biology
- Neural Networks
- Bayesian and probabilistic learning
- Fuzzy sets
Large-example-set approaches appropriate for context problems?

Problem is, user interactions don’t usually generate large numbers of examples

Large-scale techniques often have trouble with explaining “what happened”, control issues

Best for unsupervised learning, data mining

Users don’t have patience for slow learning

Good for “noisy data”
Statistical approaches: Clustering

Which go together?
Discrimination Net

Attributes:
- Domain?: Animal, Vegetable, Mineral
- Coverage?: Feathers, Hair, Bald
- Can fly?: Yes, No

Diagram:
- A??
- AF?
- AFY
- AFN
- AH?
- AHY
- AHN
- AB?
- ABY
- ABN
- A?Y
- A?N
Feature selection problem

Out of the all the possible features that affect a decision, which actually do?

Pick relevant aspects of context

Cima feature selection Mulsby

Classify, Find, Generate, Modify
The Frame Problem in AI

When you change the context of an assertion, what changes?

Difficult to say all the possible things that might affect an assertion
Circumscription

Birds fly.

Tweety is a bird.

Therefore, Tweety flies.

... unless Tweety is a penguin or ostrich, Tweety broke his wing, Tweety is underwater, Tweety is a stuffed bird, ... .

Inferences are circumscribed by context
Everything takes [implicit] context argument
Default reasoning, nonmonotonic reasoning

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Inference rules take "extra argument" of context