Graphical Models for Decision Making

Lesson 1, week 12, class 23

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Contens

1 Introduction

Outline of Contens

1 Introduction

Decision Analysis $\rightarrow$ Decision Support Systems

- Complex problems: uncertainty, risk, (multi)objectives, dependencies among variables, preferences over outcomes, . . .
- The Models are a tool for problem representation, (computational) evaluation and (deep) understanding to think on the problem.
- Prescriptive approach: Descriptive + Normative.
- Better decisions: coherent and rational process. Not guess the future or improve our luck.

Inmanuel Kant
"All our knowledge begins from sense (Observation), passes understanding (description and modeling) and ends in reason (inference)"

Decision Analysis Cycle

Dialogue between analist and decision maker (DM)

1. Problem Identification
2. Tree of Goals (Static or Dynamic)
3. Decision Alternative set
4. Decision Model
   - i Structure
   - ii Uncertatinty
   - iii Preferences
5. Optimal Alternative Evaluation
6. Sensitivity Analysis
7. Validation No {goto 1,2,3 or 4} / Yes {next}
8. Optimal Alternative Implementation

A. Einstein
"Everything should be made as simple as possible, but not one bit simpler"

Frequentist Probability

Experiments: repetive framework, Assesing using data

Subjective Probability

Bets: degree of belief, personal judgment, Assesing by experts (Cognitive heuristics → biased assignments)

Bayes Theorem → Belief Revision (Learning)

- Diagnostic test (+/-) over a process or outcome

	present	absent
+	TP	FP
-	FN	TN

- Sensitivity ($TPR = P(+|present) = TP/(TP + FN)$) and Specificity ($TNR = P(-|absent) = TN/(TN + FP)$); $FNR = 1 - TPR, FPR = 1 - TNR$
- Bayes: posterior probability, $P(present|+) = \frac{P(+|present)P(present)}{P(+|present)P(present)+P(+|absent)P(absent)}$

Utility

DM should balance preferences over consequences and uncertainty over outcomes. Our utility model is for discrete variables and it is a table over the attibutes

- Utility Theory: Axioms (A1-A7), Properties (scale, positive affine transformations, $u(x_1) = 1, u(x_n) = 0$)
- X, $x_i \succsim x_j \Leftrightarrow u(x_i) \geq u(x_j) \forall x_i, x_j \in X$
- Under uncertainty the decision maker must choice between lotteries for each alternative and the consecuences (prizes)
- Assesing utitly function, compare sure prizes $< 1, x_s >$ and reference lottery $< p, x_1; 1-p, x_n >$, Methods:
  - certainty equivalence: search for x_s
  - probability equivalence: search for p
- Assesing multi-attribute Utility

A. Machado
"Every fool confuses value with price"

Graphical Models for Decision Making

Probabilistic graphical models: Graph theory + Probability Theory + Decision Theory

Probabilistic graphical models are an elegant framework which combines uncertainty (probabilities) and logical structure (independence constraints) to compactly represent complex, real-world phenomena. The framework is quite general in that many of the commonly proposed statistical models (Kalman filters, hidden Markov models, Ising models) can be described as graphical models. Graphical models have enjoyed a surge of interest in the last two decades, due both to the flexibility and power of the representation and to the increased ability to effectively learn and perform inference in large networks. (Daphne Koller, Nir Friedman, Lise Getoor and Ben Taskar)

- Decision Tables (Decsion, one)
- Decision Trees (Decsion, sequential)
- Bayesian Networks (Diagnosis, aposteriory)
- Influence Diagrams (Decsion, general, ID = BN + Decisions + Utility)
- ...

Decison Making

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- Clemen, R.T. (1996) Making Hard Decisions, Duxbury Press
- J. Pearl. Probabilistic Reasoning in Intelligent Systems. Morgan Kaufmann, San Mateo, CA, 1988.
- Report MSR-TR-95-06, Microsoft Research, Seattle, WA, 1996. [5] F. V. Jensen. Bayesian Networks and Decision Graphs. Springer-Verlag, New York, 2001.

Graphical models

- Howard, R.A., Matheson, J.E. (2005) Influence Diagrams, Decision Analysis, 2, 3, 127-143
- Bielza, C., Gómez, M., Shenoy, P.P. (2011) A Review of Representation Issues and Modelling Challenges with Influence Diagrams, Omega, 39, 227-241
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- R.D. Shachter, Evaluating influence diagrams, Op. Res., 34 (1986), pp. 871–882
- M. Henrion, Propagation of uncertainty by probabilistic logic sampling in Bayes' networks, J. Lemmer, L.N. Kanal (Eds.), Uncertainty in Artificial Intelligence, Vol. 2, North-Holland, Amsterdam (1988) Vol. 2

Software Tools

- R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.
  Packages:
  bnlearn, deal, pcalg, catnet, mugnet, bayesclass $\rightarrow$ learning
  gRbase, gRain $\rightarrow$ inference
- GeNie
- Bayesia
- Netica
- Hugin
- ...

- Introduction
- Decision tables and decision trees.
- Beyesian networks
- Influence diagrams
- Practice: problems + models + evaluation + analysis
- Qualification: deliver solution of practical exercises

¿Remarks and Questions?

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