Introduction to Decision Support Systems

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http://aragorn.wi.pb.bialystok.pl/~druzdzel/

Outline

- **Communication**
- **Organization of the course**
- **What is decision analysis?**
- **Contents of the course**
- **Course outline**

● **Introducing each other**
Organization of the course
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The instructor

Marek J. Drużdżel

Profesor PB, Wydział Informatyki, Politechnika Białostocka

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WWW   : http://aragorn.wi.pb.bialystok.pl/~druzdzel/

**How can I contact you in case of
emergencies/schedule changes?**

(will need to changes the dates of some meetings)

Organization of the Course

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Objective of the course
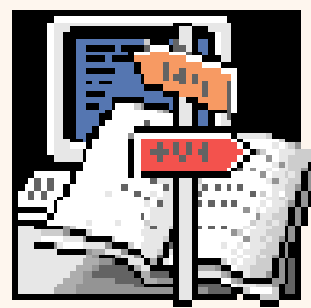
The primary objective of this course is to make you acquainted with the foundations of decision making and decision support, as developed in mathematics and computer science.

You will learn a set of tools for decision making known under the umbrella name of *decision analysis* and how these relate to building decision support systems.

I expect that you will learn:

- **How to use simple techniques for improving your own intuitive judgment and decision making under uncertainty.**

- **How to apply the tools of decision analysis to aid decision-making under uncertainty.**

- **How to employ decision-analytic methods in intelligent information systems and decision support systems.**

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Meeting times
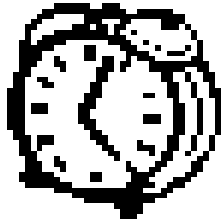
Lectures (Room B5/WA-12B):

Tuesdays, 4:00-5:30pm

PS (Room A228/223):

Tuesdays, 12:00-1:30pm & 2:00-3:30pm

Marek's office hours (Room A127/136):

Wednesdays, 10:15-11:45am or by appointment

Workshop meetings

- **Fifteen meetings that aim at practicing the material introduced during the lectures**
- **You need to be prepared for the meetings in order to avoid wasting time!**
- **I will try to stimulate preparation by five entrance tests.**

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The textbook
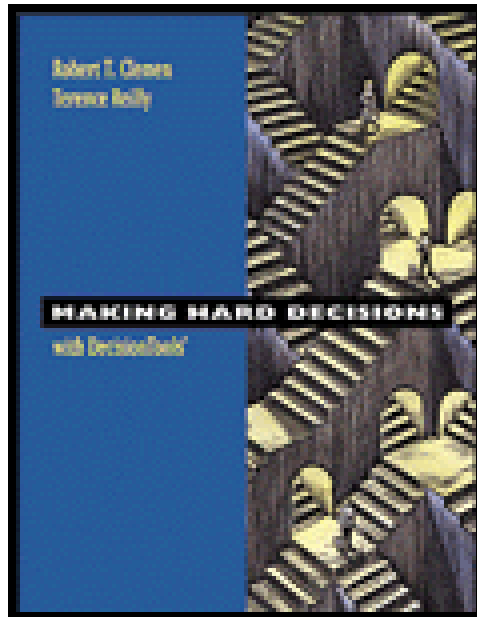
Robert T. Clemen & Terence Reilly *"Making Hard Decisions with Decision Tools."* **Second Revised Edition, Duxbury Thomson Learning, Belmont, California, 2001, ISBN 0-534-36597-3**

Other editions are just fine.

Course materials

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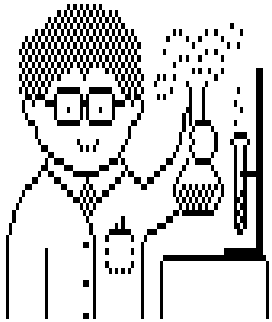**http://aragorn.wi.pb.bialystok.pl/~druzdzel/swd.html**

The above page is accessible from my home page at WI/PB:

http://aragorn.wi.pb.bialystok.pl/~druzdzel/

Term project

Team work (team size four or less, possible larger groups by permission).
Solving a real decision problem and building a decision support system that will support it.
Deliverables: (1) a project proposal, (2) a mid-semester progress report, and (3) a final report.

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Exam (last lecture meeting)

The final, comprehensive exam will contain:
- **problems and analyses covered in class and in the workshop meetings**
- **short answer questions**

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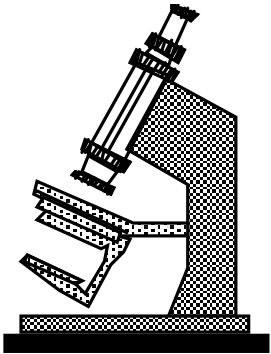Contents of the course
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Expected effort (time load)

Expect to spend about five hours quality time outside of class for every class meeting to do the readings. If you keep up with readings and do the laboratory assignments well, you should not need much extra time to prepare for the exams.
The term project should normally demand between twenty and thirty hours of your time.
The actual load will vary, of course, depending on your background and preparation.

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Grading

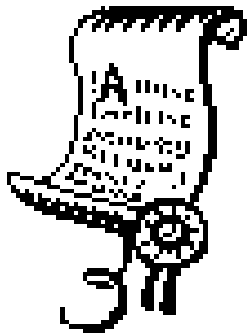Your final grade for the course will be determined as follows:

Entrance tests : 20%
Term project   : 30%
Final exam   : 50%

I reserve the right to increase the total score by up to 10%, generally as a reward for class participation.

Useful Advice (Hopefully)
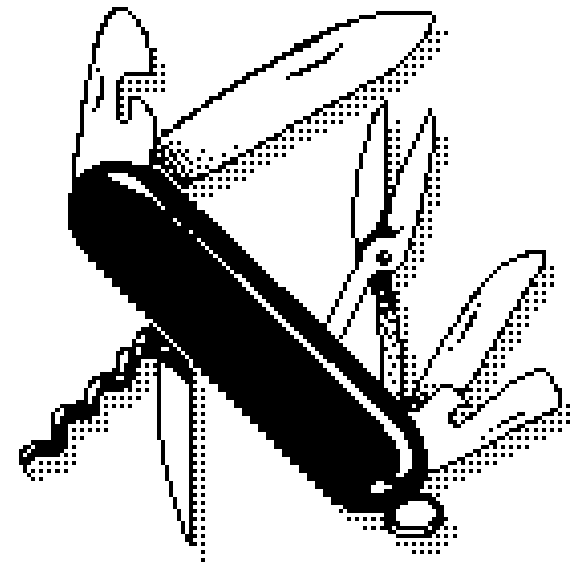
Come to our meetings …
... and be their active participant

- **Being there is important.**

- **Our in-class discussions and exercises will play a role in your learning.**

- **Understanding difficult parts of the material on your own may often cost you a multiple of what it takes in class.**

Do not hesitate to ask questions, interrupt me if needed

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Be good to your classmates
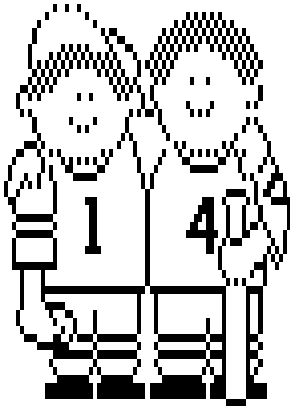
As somebody in a biology lab has once put it:
"if you are a good colleague, you will not need to be afraid that somebody pisses in your cultures when you are not in the lab."

All work in this course (except for the exams) is collabortive.

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Do the readings (before the class)

You will be amazed how efficient you will be in your studies!

What is Decision Analysis?

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What is a good decision?

As many good questions, this question does not have a crisp-cut answers ☺.

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Can you judge decisions by their outcomes?

The story of Bill and Bob

What is a good decision then?

One possible answer:

- **One that results from a good decision making process**

- **Improving decisions means mostly improving the decision-making process.**

- **A nice criterion for good decisions is to "look forward and back." Imagine yourself in the future, looking back at your own decision now. Will you be able to say regardless of the outcome: "Given everything I knew at that time — and I did a pretty good job of digging out the important issues — I made the appropriate decision. If I were put back in the same situation, I would go through the process pretty much the same way and would probably make the same decision." If your decision making lets you say this, then you are probably making good decisions.**

- **The issue is not whether you can foresee some unusual outcome that really is unforeseen, even by experts. The issue is whether you carefully consider the aspects of the decision that are important and meaningful to you.**

Decisions, decisions …
(or Human Decision Making Under Fire)

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Decades of laboratory work demonstrating that we are not too good in judgment and decision making ☹

My favorites
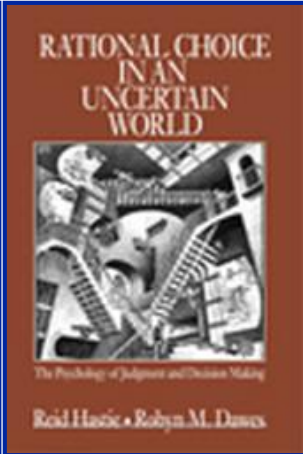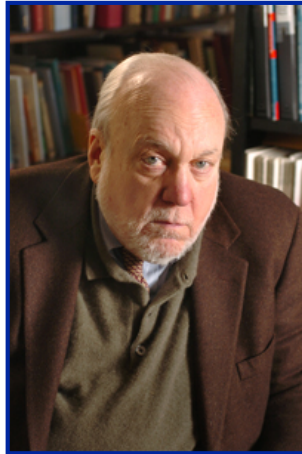
Robyn Dawes

Herb Simon
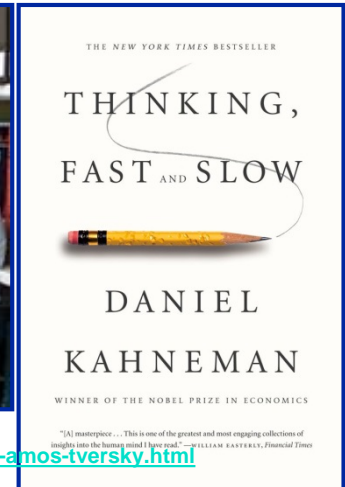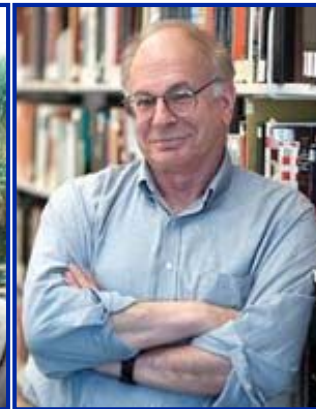
Daniel Kahneman and Amos Tversky

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But how do we do in real life? College admissions

Admissions committee in University of Oregon's Psychology Department and proper and improper linear models were compared to faculty ratings of students 2 to 5 years after matriculation.

Observed correlations:
- **0.19 with the admissions committee**
- **0.38 with proper model (half sample)**
- **0.48 with improper model (weights 1.0 and -1.0)**

http://www.calu.edu/current-students/new-student-resources/index.htm

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But how do we do in real life? Medical school admissions

University of Texas medical school. The admissions process has two steps. First, all applicants are screened for likelihood for academic success; criteria include academic performance, assessment by advisers, etc. Second, applicants who meet the criteria are interviewed; those with the best rankings are accepted.

In 1979, 150 students were selected. Afterwards, 50 more had to be accepted from those who had been interviewed but rejected.

This gave an excellent opportunity (an experimental setup!) to compare the performance of medical students who had been initially accepted and initially rejected. It turned out that there was no meaningful difference in performance between both groups.

The interview process does not seem to be worthwhile as a predictive tool.

http://dukeeyecenter.duke.edu/modules/eyectr_student/index.php?id=5

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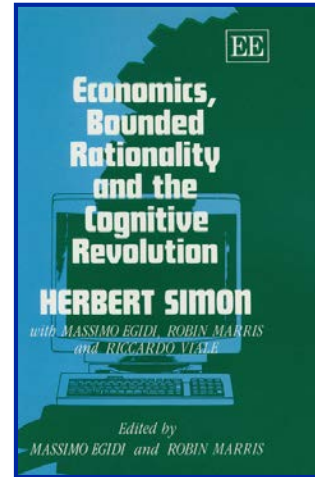# But how do we do in real life? Prediction of violent behavior of psychiatric patients

A simple model that looked at past instances of violent behavior in psychiatric patients performed better than a panel of psychiatrists in predicting future violent behavior.

http://boards.weddingbee.com/topic/new-dress-designs-for-mother-in-laws#axzz2Lx28EtHt

But how do we do in real life? Prediction of marital happiness

A simple model that subtracted the average number of fights a week from the average number of incidences of sexual intercourse a week performed better than marital therapists

http://articles.chicagotribune.com/2013-04-09/features/sc-fam-0409-marriage-counselor-20130409_1_couples-therapy-relationship-counseling/

http://www.justinstum.com/marriage-and-couples-counseling-in-st-george/

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Where does the difficulty come from?
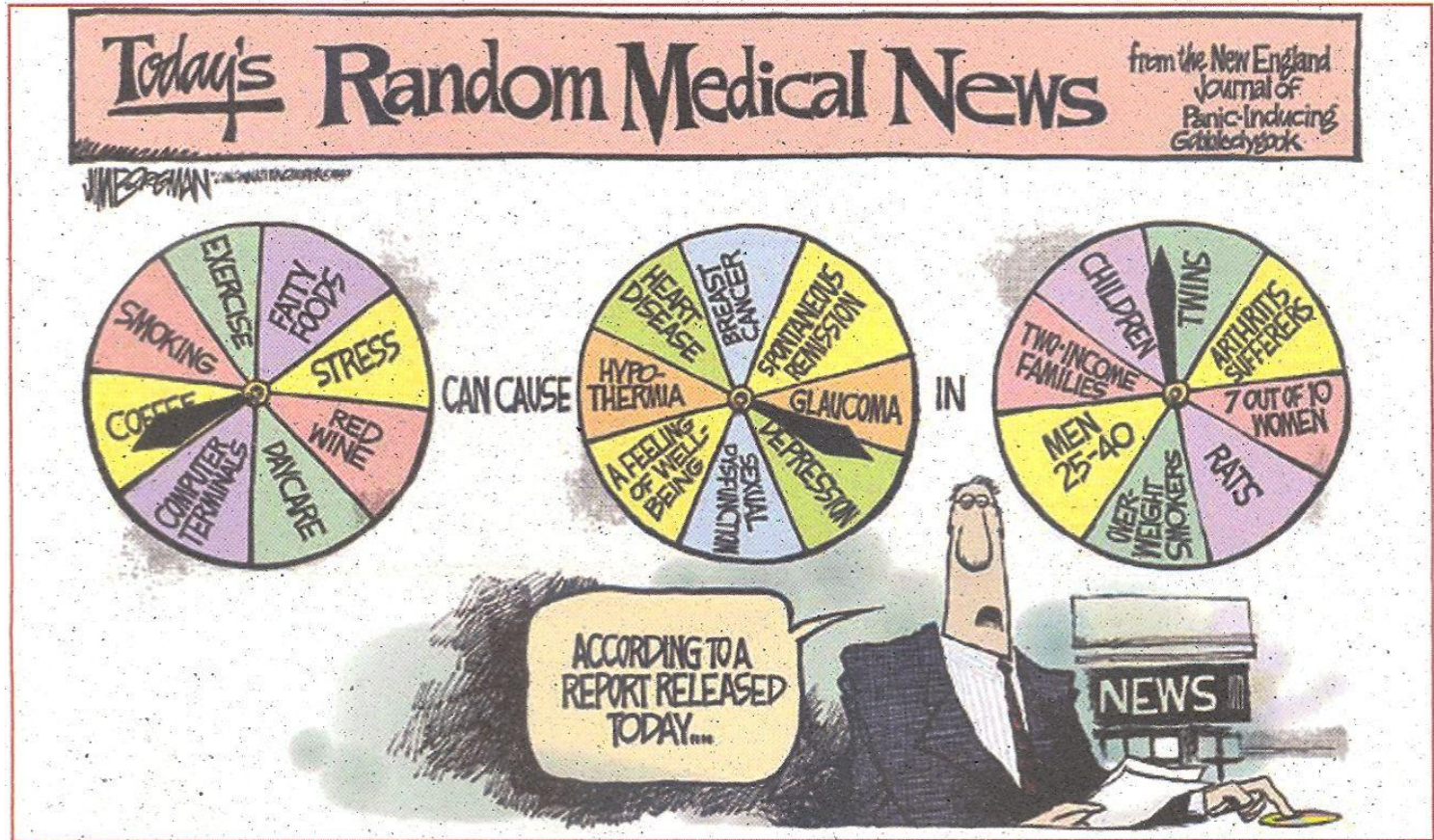
©4/27/97 Jim Borgman, Cincinnati Enquirer.
Reprinted with special permission of King Features Syndicate.
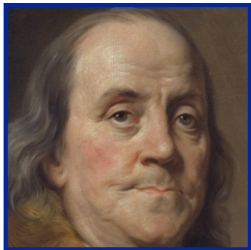
"*... in this world nothing can be said to be certain, except death and taxes*" –Benjamin Franklin in a letter to his friend M. Le Roy

(*) *The Complete Works of Benjamin Franklin*, John Bigelow (ed.), New York and London: G.P. Putnam's Sons, 1887, Vol. 10, page 170

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Where does the difficulty come from?

- **Complexity**
- **Conflicting objectives**
- **Many decision alternatives**
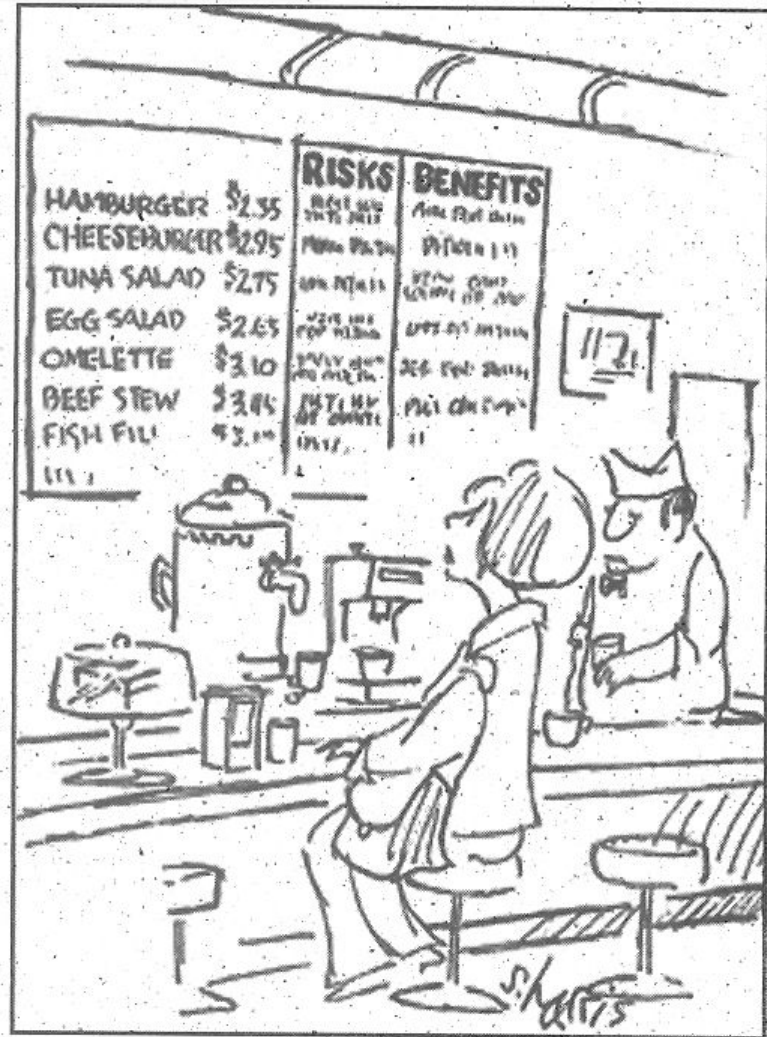
© 1979 Sidney Harris. Reprinted with permission from Sidney Harris. All rights reserved.

Where does the difficulty come from?

- **Multiple decision makers and their perspectives**
- **Our cognitive limitations**
- **High stakes**
- **Time pressure**

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Human decision making

(In most tasks requiring analytical thinking,) in situations of sufficient complexity, even the dumbest mathematical models perform consistently better than humans.

"The glass is half-full" approach:

There is a lot of room for improvement!

http://www.jessicasimien.com/whit-wisdom-make-a-decision/

Elements of Decision Analysis

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Decision support

Are people good at decision making?

A similar question:

Are people good at arithmetics?

Why not use a calculator ☺?

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Decision theory and decision analysis

John von Neumann & Oskar Morgenstern

Decision theory (1920s-1930s):

A mathematical theory of how decisions should be made

(based on the idea that uncertainty and preferences should combine like mathematical expectation)

Decision analysis (1960s+):

The art and craft of applying decision theory in practice

Ronald Howard   Howard Raiffa

Decision Analysis

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Challenge:

Identify what people are good at and support what they don't do too well

- **It seems that people are much better at selecting and coding information (what to look for, what factors to consider) than they are at integrating it.**

- **This is a fundamental assumption of decision analysis, but one that has been verified in practice by numerous studies.**

- **Decision analysis is an aid to human decision making, just as a calculator is an aid to our limited capability for mental arithmetic.**

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Elements of decisions

Decisions are made everywhere, including science. What are their elements?

- **Preferences (a.k.a. objectives)**
- **Actions (a.k.a. decision options)**
- **Uncertainty (nuisance but, unfortunately a fact of life ☹)**

Other relevant concepts:

- **Context of a decision (situation)**
- **Consequences (outcomes)**
- **Dynamic character of decision problems (often leads to sequential decisions)**

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The goal of decision analysis
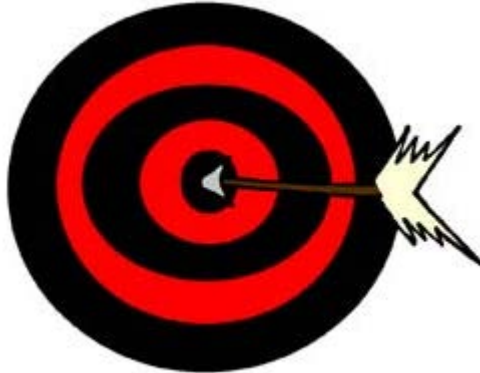
Insight not numbers!

- **Decision analysis provides structure and guidance to thinking systematically about hard decisions**
- **A DA exercise will be successful if the decision maker has learned something about the problem**
- **Sometimes it offers justification of previously made choices, but even then it is useful by offering insight**

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Normative vs. descriptive decision support

- **Traffic laws vs. actual behavior of drivers**
- **Bible vs. actual behavior of people**

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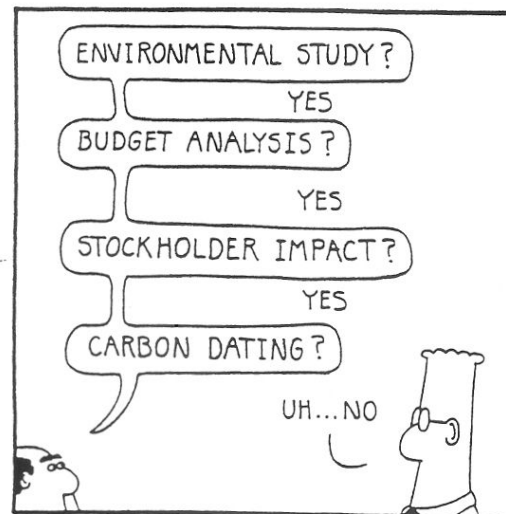
Bayes theorem and Bayesian statistics

A versatile and powerful theory that seems to solve a variety of problems, originating from an 18th century English mathematician, Rev. Thomas Bayes (http://en.wikipedia.org/wiki/Thomas_Bayes)

the theory that would not die

how bayes' rule cracked the enigma code, hunted down russian submarines & emerged triumphant from two centuries of controversy

sharon bertsch mcgrayne

Bayes Theory is so "hot" that a lightly written book "The Theory That Would Not Die," published in 2011, has become a bestseller

Recommended video:
http://www.youtube.com/watch?v=8oD6eBkjF9o

Bayesian modeling is reliable and it solves hard problems.

It can use both, data and expert knowledge.

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What is the relation of Bayesian statistics to classical statistics?

What is **p(** **)** ?

Classical statisticians: "We have no clue ☹. Probability is a limiting frequency. A nuclear war is not a repetitive process."

Bayesians: "0.24 ☺. Probability is a measure of belief"

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"Immeasurables"

Some things are difficult to express in numerical terms.

Imagine that you are a juror. How much is it worth to condemn an innocent man or to release a guilty one?

How do you judge money vs. health or happiness?

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The need for utility

Even if you can express "immeasurables" in numbers, there are problems with expected value, found quite a while ago (even though probability is quite young).

Bernoulli (17th century) pointed out these problems and the need to have some measure of preferences.

Then there was long nothing, just a qualitative, ordinal notion (note the gymnastics around qualitative notion of utility in economics) and finally a quantitative, cardinal utility in 1940s due to von Neuman & Morgenstern.

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Applications

Numerous!

- **Medical diagnosis, prognosis, therapy planning**
- **Fraud detection**
- **Machine diagnosis and prognosis (in the context of machine maintenance)**
- **Diagnosis of database servers**
- **Diagnosis of airplanes, diesel locomotives, IC "baking" devices**
- **Data analysis**
- **Strategic planning**
- **…**

Software demo

- **Simple models**
- **Diagnostic applications**
- **Learning**
- **Qualitative models**
- **Dynamic models**
- **Equations**

GeNIe

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A developer's environment for graphical decision models (https://www.bayesfusion.com/).

Qualitative interface: QGeNIe

Learning and discovery module: SMiner

Diagnosis: Diagnosis

Model developer module: GeNIe.

Implemented in Visual C++ in Windows environment.

Wrappers: SMILE.NET jSMILE, rSMILE, PySMILE, SMILE.COM, Pocket SMILE

Allow SMILE☺ to be accessed from applications other than C++compiler

Reasoning engine: SMILE☺ (Structural Modeling, Inference, and Learning Engine).

A platform independent library of C++ classes for graphical models.

Diagnosis

GeNIe

SMILE.NET☺

Pocket SMILE☺

SMiner

jSM

SMILE☺

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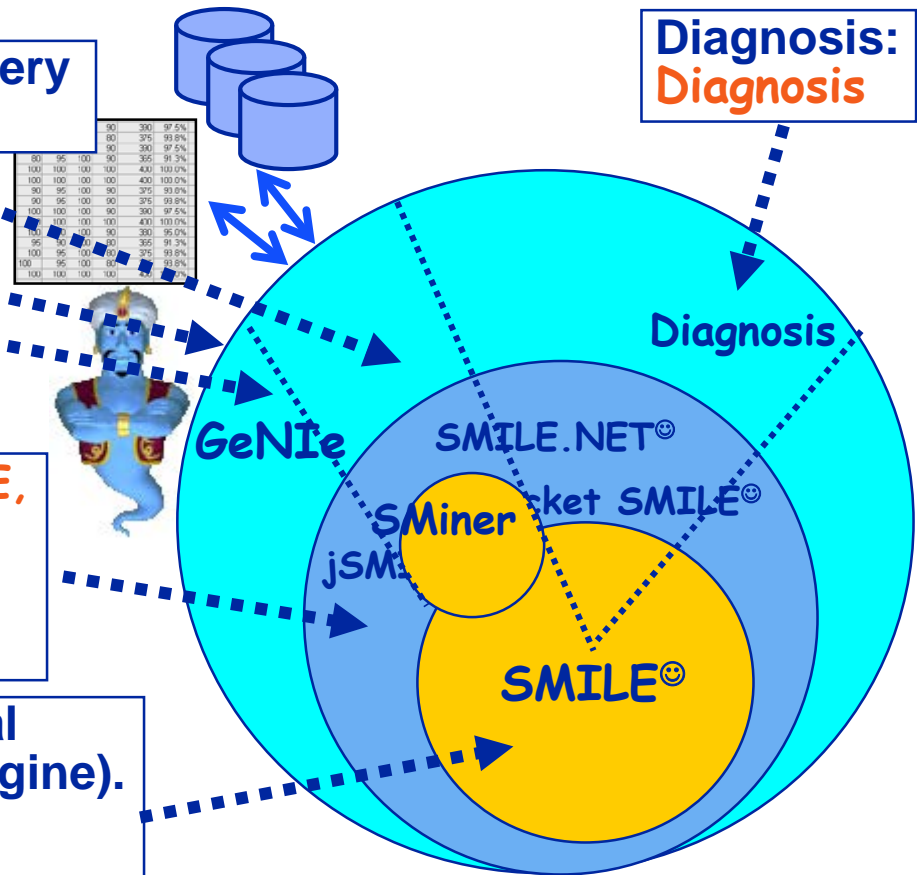
Learning/Data Mining

GeNIe/SMILE© have the capability to analyze data, discover causal patterns in them, and build models based on these data.
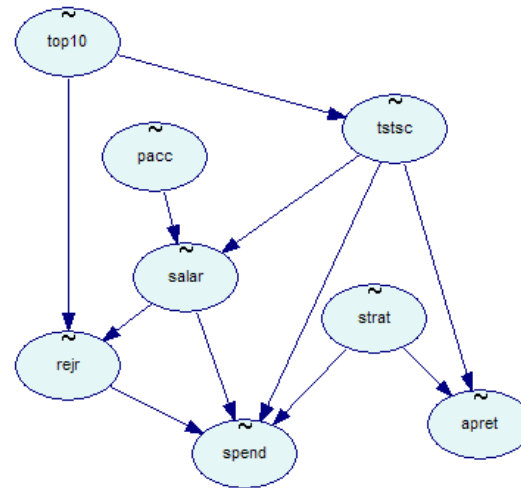
causal structure
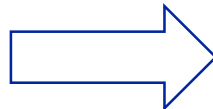
numerical parameters

data

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Temporal reasoning

Temporal models allow for tracking development of a system over time and support decision making in complex environments, where not only the final effect counts.
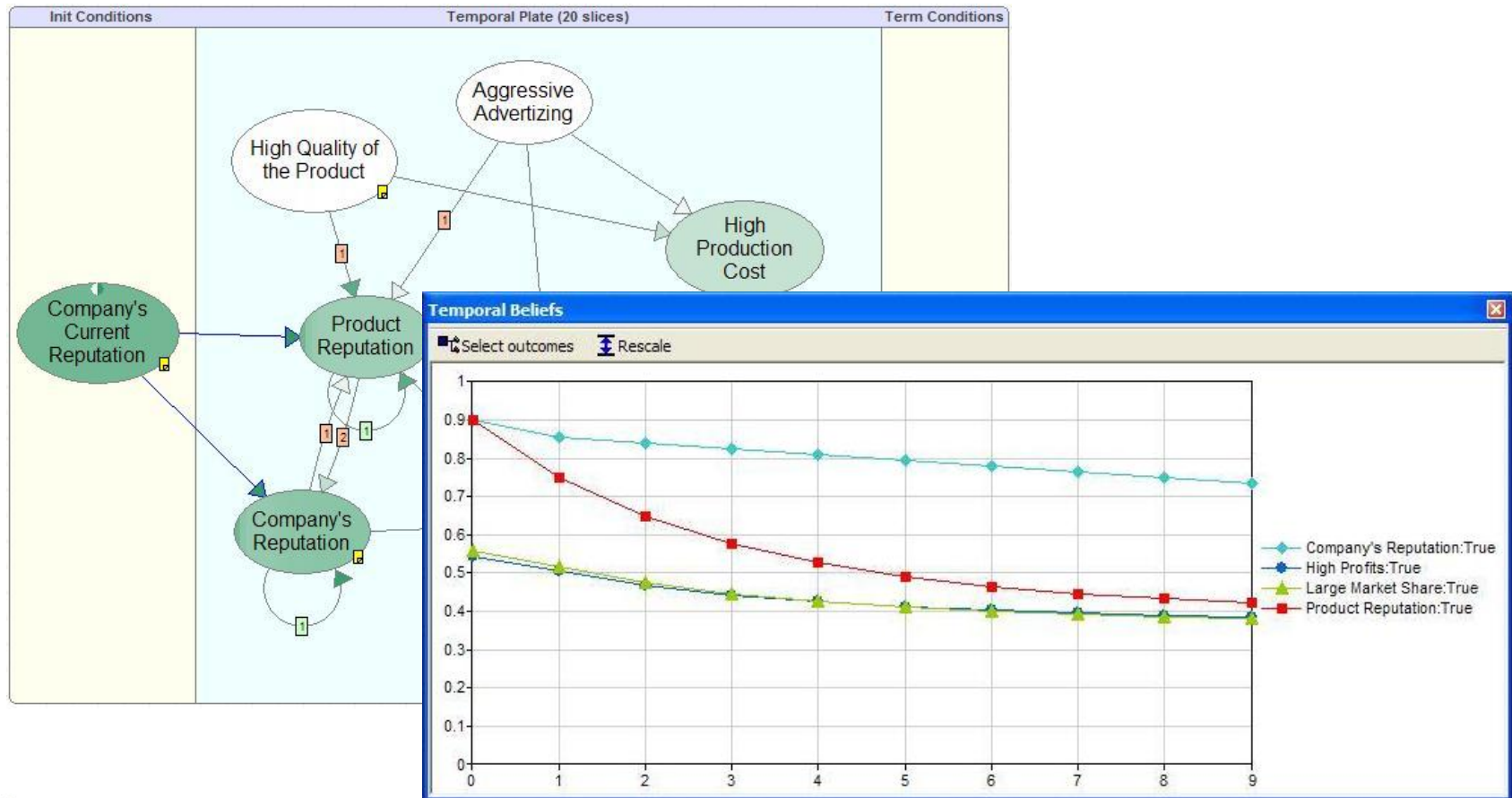
HEPAR II Model
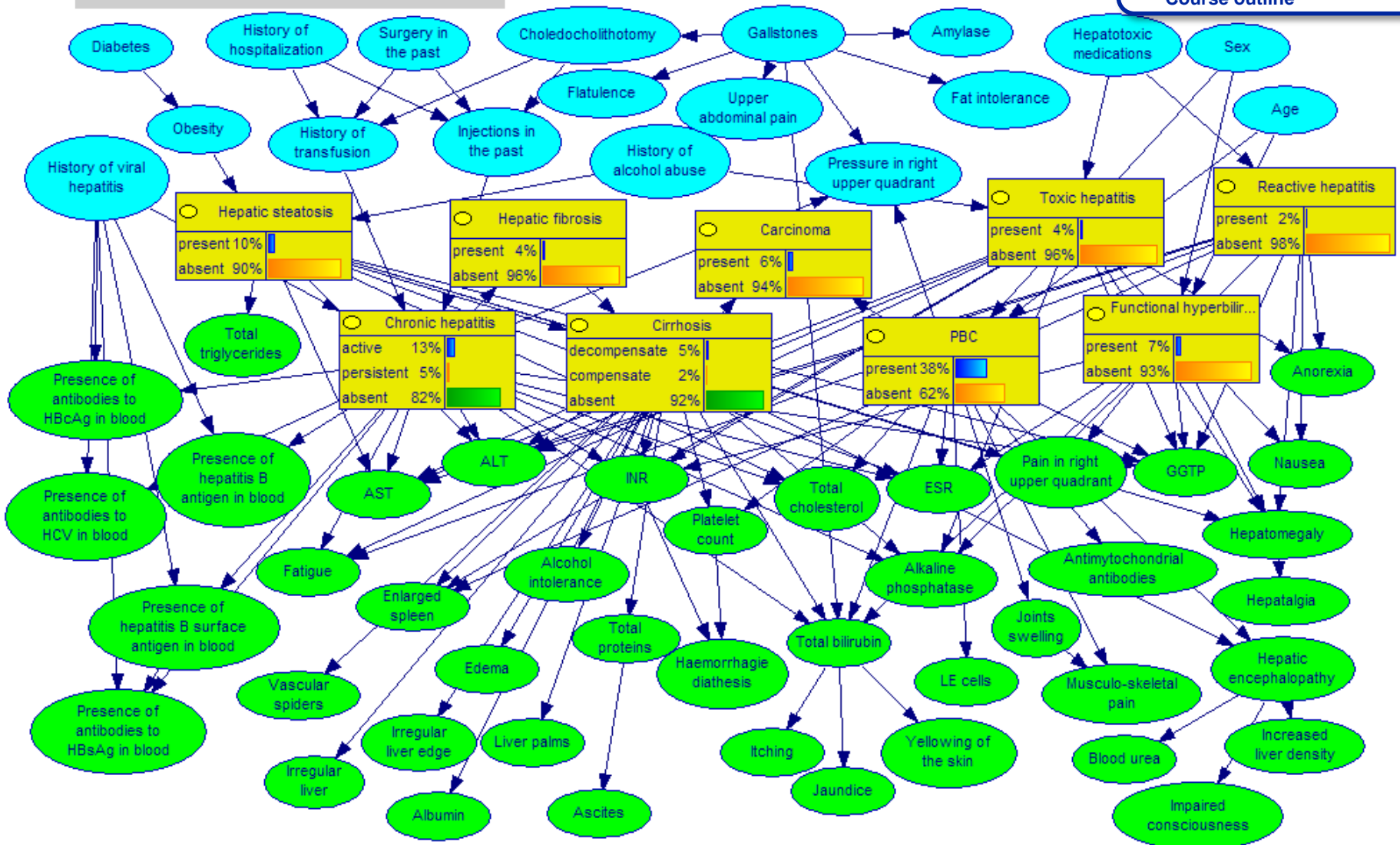
70 variables; 2,139 numerical parameters (instead of over $2^{70} \approx 10^{21}$!)

Pittsburgh Cervical Cancer Screening Model

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infection_name

Candida	0%
Chlamydia	0%
Coccobacilli	0%
Condyloma	0%
Herpes	0%
HPV_NEGATIVE	0%
HPV_POSITIVE	1%
NA	99%
Trichomonas	0%

Age

a1_below_20	0%
a2_20_29	0%
a3_29_45	100%
a4_45_60	0%
a5_60_up	0%

Race

Black	0%
Other	0%
Unknown	0%
White	100%

HPV

NA	0%
Negative	0%
Positive	100%
Qns	0%

other_hist_name

AGUS	0%
Bleeding	0%
CIN1	0%
CIN2_CIN3	100%
Dysplasia	0%
Abnormal_Pap	0%
Lesion	0%
Abn_Endometrial_S...	0%
NA	0%

Polyps

yes	1%
no	7%
NA	91%

cervix

NA	18%
benign	9%
CIN1	14%
CIN2_CIN3_AIS	54%
carcinoma	1%
carcinoma_not_cervical	0%
VAIN1	0%
VAIN2_VAIN3	0%
vaginal_carcinoma	1%
benign_vagina	1%

contraception_name

Birth_Control_Pills	0%
Condom	0%
Contraceptives	9%
Depoprovera	1%
Hormonal	0%
IUD	1%
NA	88%

menst_name

Post_Menopausal_Bleeding	0%
Irregular	0%
Post_Menopausal	5%
Menopause	1%
Post_Partum	0%
Hysterectomy	0%
Pregnant	0%
NOT_GIVEN	0%
NA	94%

cancer_name

Breast	0%
Cervical	0%
Endometrial	0%
NA	99%
Other	0%
Ovarian	0%
Uterine	0%
Vaginal	0%
Vulvar	0%

Uterus

uterine_carcinoma	0%
benign	4%
NA	96%

Ovary/fallopian tube

benign	0%
ovarian_carcino ...	0%
NA	100%

hysterectomy

yes	1%
no	82%
NA	17%

part_name

Cervix	98%
Vagina	2%

feecode_name

Pap	3%
TP	0%
TP_imaged	97%

interpretation_name

Adenocarcinoma	0%
Adenocarcinoma_other	0%
AGC	0%
AGC_Endocervical_Cells_Atypi...	0%
AGC_Endometrial_Cells_Atypical	0%
ASC_H	0%
ASCUS	0%
LSIL	0%
HSIL	100%
Negative	0%
No_Primary_Interpretation	0%
Squamous_Cell_Carcinoma	0%
SUSP_Malignant_Cells	0%
VLSIL	0%
VHSIL	0%

proc

Bx	44%
CONE	16%
ECC	17%
EMS	1%
Excisional_Bx	0%
HYSTERECTOMY	1%
NA	17%
POLYPECTOMY	1%
TRACHELECTOMY	0%
VAGINAL	3%

adequacy_name

Satisfactory	2%
Satisfactory_EC	81%
Satisfactory_No_EC_TZ	16%
UNSAT	1%

[Oniśko et al.] 18 variables; 295,163 numerical parameters

Diagnosis, prediction, prognosis

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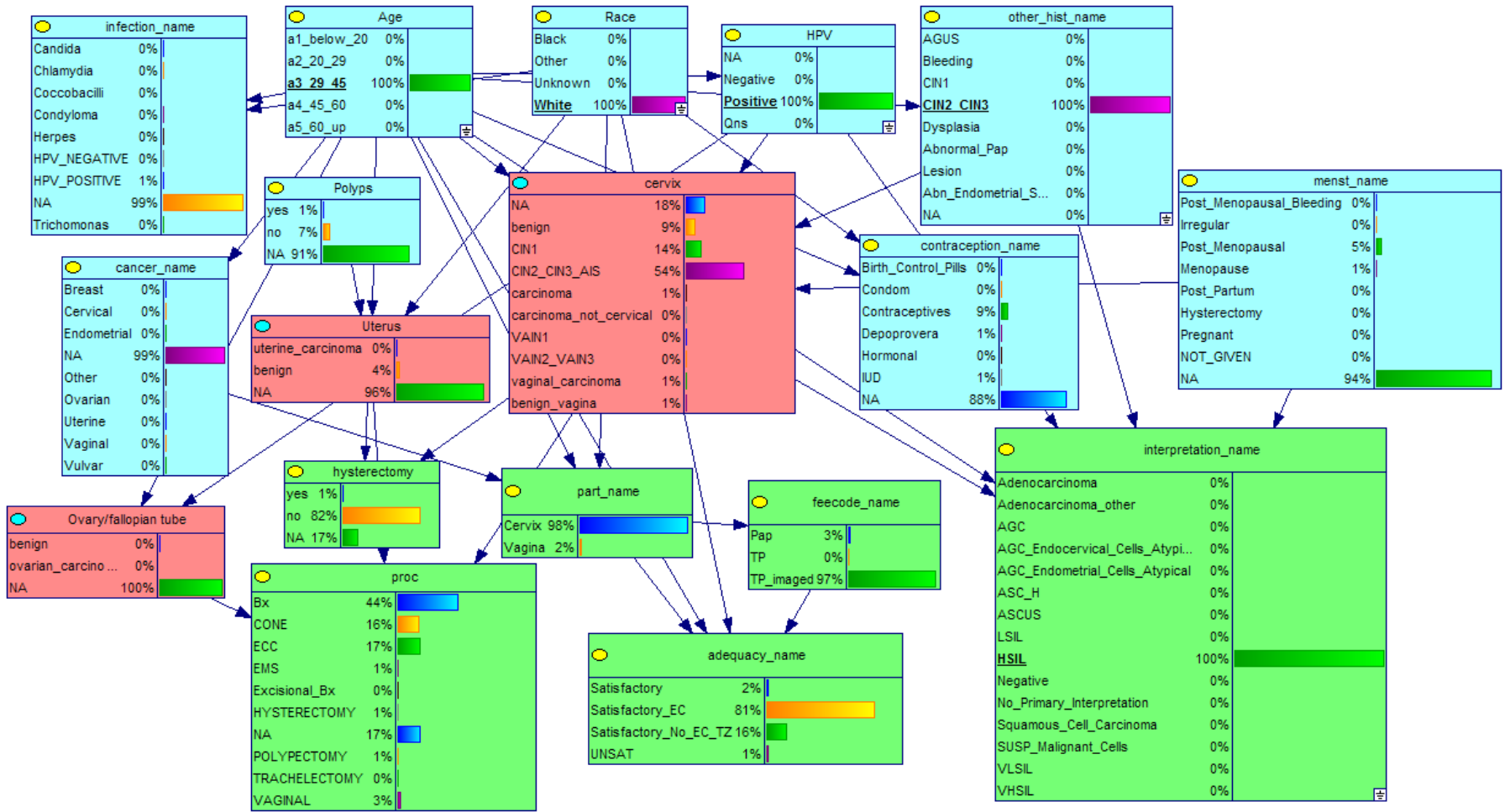● What is decision analysis?
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Symptomate: An intelligent medical consultant

http://www.doktor-medi.pl/
http://www.symptomate.com/
http://dxmate.com/

https://symptomate.com/

Modeling engineering and financial processes

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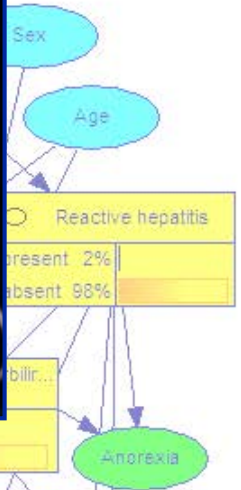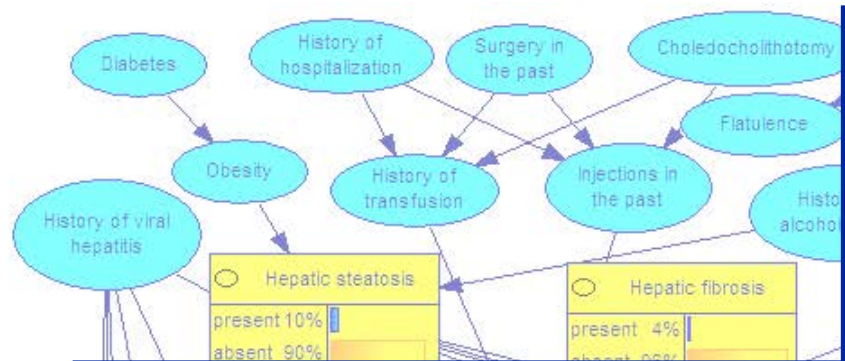**Outside Air Temperature**

15 .. 17	5%
17 .. 19	8%
19 .. 21	10%
21 .. 23	16%
23 .. 25	18%
25 .. 27	17%
27 .. 29	14%
29 .. 31	8%
31 .. 33	4%

Outside Air Damper Control Signal

0 .. 0.5	49%
0.5 .. 1	51%

Return Air Temperature

24

Mixed Air Temperatu...

10 .. 12	0%
12 .. 14	0%
14 .. 16	0%
16 .. 18	1%
18 .. 20	4%
20 .. 22	10%
22 .. 24	32%
24 .. 26	35%
26 .. 28	12%
28 .. 30	4%
30 .. 32	1%
32 .. 34	0%
34 .. 36	0%
36 .. 38	0%
38 .. 40	0%

Cold Water Flow Rate

0 .. 0.4	0%
0.4 .. 0.8	0%
0.8 .. 1.2	2%
1.2 .. 1.6	7%
1.6 .. 2	15%
2 .. 2.4	26%
2.4 .. 2.8	26%
2.8 .. 3.2	18%
3.2 .. 3.6	6%
3.6 .. 4	1%

An equation relating temperatures before and after the damper:

$$Tma = Toa \cdot u\_d + Tra \cdot (1-u\_d)$$

If there is only cooling (u_hc == 0)

$$m\_flow\_ma \cdot sp\_heat\_air \cdot (Tsa - Tma) = mdot\_cw \cdot sp\_heat\_water \cdot (T\_cw\_out - T\_cw\_in)$$

and if there is only heating (u_cc ==0)

$$m\_flow\_ma \cdot sp\_heat\_air \cdot (Tsa - Tma) = mdot\_hw \cdot sp\_heat\_water \cdot (T\_hw\_out - T\_hw\_in)$$

Cold Water Inlet Temperature

6.67

Specific Heat Air

1....

Specific Heat Water

4.1...

Cold Water Outlet Temperature

8 .. 9	8%
9 .. 10	19%
10 .. 11	28%
11 .. 12	21%
12 .. 13	12%
13 .. 14	6%
14 .. 15	3%
15 .. 16	2%
16 .. 17	2%

Mixed Air Flow Rate

4.56 .. 4.6	44%
4.6 .. 4.67	56%

Supply (Discharge) Air Temperature

14 .. 14.5	0%
14.5 .. 15	41%
15 .. 15.5	58%
15.5 .. 16	0%

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Detection

- **Spam detection**
- **Fraud detection**
- **Detection of conflicting medicine**

http://sciencebasedpharmacy.wordpress.com/tag/drug-regulation/

www.jesperdeleuran.dk

http://californialoanfind.com/what-and-who-is-teletrack/

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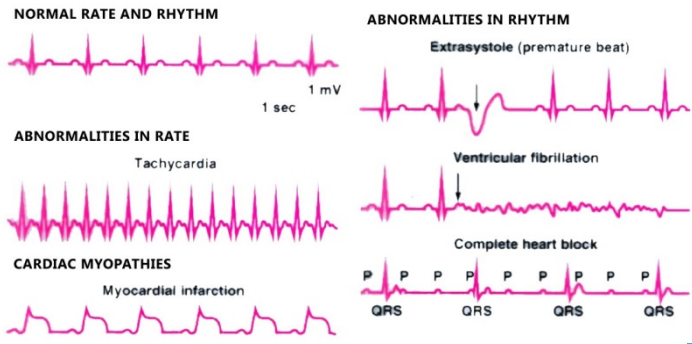● What is decision analysis?
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Recognition

- **Handwriting recognition**
- **Face recognition**
- **Optical character recognition**
- **Pattern recognition**
- **Speech recognition**

http://www.stanford.edu/class/cs224s/

http://www.ivline.info/2010/05/quick-guide-to-ecg.html

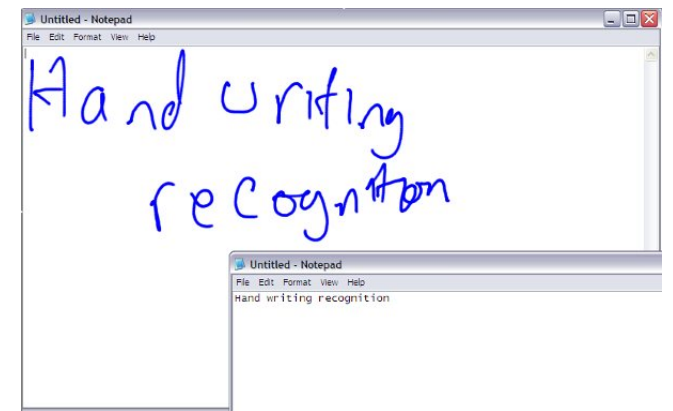http://www.l1id.com/pages/116-face   http://networkprogramming.wordpress.com/2009/09/

Recommender systems

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An effective way to enhance customer shopping experience and increase sales

Customers who bought The Thing [1982] also bought:

An American Werewolf in London : Two Disc 21st Ar
DVD ~ David Naughton
Release Date: October 10, 2005

Used & new from £3.00

☐ I Own It   ☐ Not interested   x|☆☆☆☆☆ Rate it

The Fog [1979]
DVD ~ John Houseman
Release Date: October 18, 2004

Used & new from £3.73

☐ I Own It   ☐ Not interested   x|☆☆☆☆☆ Rate it

They Live [1989]
DVD ~ John Carpenter
Release Date: October 21, 2002

Used & new from £4.21

☐ I Own It   ☐ Not interested   x|☆☆☆☆☆ Rate it

Critically-acclaimed Movies

Based on your interest in...

SENNA

BEING ELMO A PUPPETEER'S JOURNEY

THE FIGHTER

THE GIRL WITH THE DRAGON TATTOO

GOOD WILL HUNTING
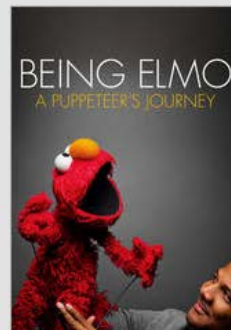
Top Rated   Most Popular

Summary

- **It is not straightforward to define a good decision**
- **Decisions are hard**
- **Decision theory is a mathematical theory of how to make rational decisions**
- **Decision analysis is the art and science of applying decision theory in practice**
- **21st century is the century of Bayes (but also of data ☺)**
- **There are many practical applications of the theory**

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What we will do in this course?

- **In this course, you will learn the principles, how to create models of decisions and how to solve these models.**

- **All this is amenable to automation.**

- **The theory is general, applicable to all familiar AI problems of agents. In Artificial Intelligence, they often used ad hoc treatment of problems. This is over now. People look at problems in a systematic fashion, using normative tools.**

Course relevance diagram

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Probability

Alternatives (decisions/action)

Creativity

Framework to Talk About the Problem

Quantification of Uncertainty

Problem Specification (Model)

Insight (this is the main goal)

Decision Trees

Risk Attitudes

Quantification of Preferences

Modeling Tools

Influence Diagrams

Utility

Bayesian Networks

Probability Trees

Single Attribute

Documentation

Dynamic Bayesian Networks

Multiple Attributes

Decision Making

Problem Evaluation

Model Refinement

Model Discovery from Data

Behavioral Decision Theory

Decision Maker

Sensitivity Analysis

Value of Information

Individual

Group

Organization

Society

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The actual contents may change as we go: I have done serious rearrangement of the contents and may make corrections as we go.

PART I: INTRODUCTION

October 1

Getting to know each other; organization and overview of the course.

October 8   *[Readings: Clemen, Chapter 1; Druzdzel&Flynn]*

Decision making; uncertainty, preferences, and actions;

motivation for decision support; decision support systems.

Rationality, rational behavior; good decisions vs. good outcomes;

foundations of decision-analytic approach to decision support.

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PART II: DECISION MODELING TOOLS

October 15   *[Readings: Clemen, Chapters 2, 3]*

Structuring decisions; decision modeling tools: influence diagrams, Bayesian networks, decision trees, probability trees. Solving decision models.

October 22   *[Readings: GeNIe on-line help, Clemen, Chapter 4]*

Structuring decisions; solving decision models.

Causality and decision analysis; examples of structuring decisions. Refinement of the topics for class projects. Final decisions regarding topics and organization of class projects.

October 29

Canonical probability distributions: Noisy-OR, -MAX, -AND, -MIN, DeMorgan gates.

(non)Importance of precision in numerical parameters.

Clarity test, sensitivity analysis, value of information.

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PART III: VARIOUS USEFUL ASPECTS OF MODELING

November 5

   Qualitative modeling.

November 12

   Using data in model construction and refining.

   Using equations in modeling (hybrid graphical systems).

November 19

   Modeling of time-dependent systems.

November 26   *[Readings: Clemen, Chapter 12]*

   Expected value of information (perfect and imperfect).

   Probability-based measures of value of information.

December 3

   TBA

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PART IV: MODELING PREFERENCES

December 10   *[Readings: Clemen, Chapters 13, 14]*

Risk attitudes.

Quantification of preferences.

Expected utility theory.

Utility elicitation, sensitivity analysis, value of information.

December 17   *[Readings: Clemen, Chapters 15, 16]*

Conflicting objectives: basic techniques, multi-attribute utility models.

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PART V: CONCLUSION

January 14   [Readings: Kleindorfer et al.; Philips]

   Combining expert opinions; group and team decision making;

   organizational and societal decision making.

January 21

   Discussion of the term projects, project presentations.

   Announcement of Marek's Best Project Award.

   Conclusion of the course.

January 28

    Final exam.