Purpose and Goals

- General understanding of methods, techniques, and systems for supporting complex real-life decision-making tasks
- Decision Analysis
  - Decision Modeling
  - Multi-Attribute Modeling
  - Software
- Decision Support and Data Mining

Data Mining

- Knowledge discovery from data
- Use of models:
  - classification
  - clustering
  - analysis
  - visualization
  - explanation
  - ...
Overview

1. Introduction:
   – What is decision-making?
   – What is decision support?

2. Decision Analysis
   – Decision Modeling:
     • stages
     • types of models
   – Multi-attribute Modeling
     • quantitative
     • qualitative
   – Software
   – Case studies

3. Decision Support and Data Mining
   – Ways to combine and integrate DS and DM
   – Case studies

Literature


http://kt.ijs.si/MarkoBohanec/pub/DEXiManual30r.pdf
Lectures: Outline

- What is Decision-Making (in the context of this course)?
- Decision Analysis
  - Decision Modeling
  - Decision Tables
  - Decision Trees
  - Influence Diagrams
  - Multi-Attribute Models
- Software
- Real-Life Applications
- Advanced Topics
  - Data Mining and Decision Support
  - Aggregation and Utility Functions
What is Decision-Making?

Decision Problem as the Problem of Choice

- Find the option that best satisfies the goals
- Rank options according to the goals
- Analyse, justify, explain, …, the decision

Questions

1. Find and describe some real-life decision problems? What are alternatives and goals in this case? What is the task?
2a. Have you been involved in a difficult decision-making problem? Which one? Why was it difficult?
2b. How did you make the decision? What did you do before and after the decision?
2c. Have you been satisfied with the decision? Was it a good or bad decision? Why?
Exercise

Identify some typical (but difficult) decision problems related to:

- your study and personal development
- management of a company
- project management
- research management
- ecology
- medicine
- economy

Types of Decisions

- Easy (routine, everyday) vs. Difficult (complex)
- One-Time vs. Recurring
- One-Stage vs. Sequential
- Single Objective vs. Multiple Objectives
- Individual vs. Group
- Structured vs. Unstructured
- Tactical, Operational, Strategic

Types and Levels of Decisions

- Strategic Support
- Management Information
- Transaction Processing
Organisational Level of Decisions

<table>
<thead>
<tr>
<th>Properties of information</th>
<th>Operational level</th>
<th>Strategic level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exactness</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Level of detail</td>
<td>detailed</td>
<td>aggregated</td>
</tr>
<tr>
<td>Time span</td>
<td>presence</td>
<td>future</td>
</tr>
<tr>
<td>Frequency of use</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Sources</td>
<td>inside</td>
<td>outside</td>
</tr>
<tr>
<td>Viewpoint</td>
<td>narrow</td>
<td>wide</td>
</tr>
<tr>
<td>Type</td>
<td>quantitative</td>
<td>qualitative</td>
</tr>
</tbody>
</table>

Characteristics of Complex Decisions

- Novelty
- Unclearness: Incomplete knowledge about the problem
- Uncertainty: outside events that cannot be controlled
- Multiple objectives (possibly conflicting)
- Group decision-making
- Important consequences of the decision
- Limited resources

So, What is Decision Support?

- No commonly agreed definition
- Very broad area, narrow definitions
- Involves or is related to disciplines:
  - Decision Sciences, Decision Theory, Decision Support Systems, Decision Analysis, Management Science, Operations Research, Artificial Intelligence
- Some keywords:
  - Theory: Utility Theory, Game Theory, Theory of Choice
  - Data: Databases, Data Warehouses
  - Models: Deterministic, Stochastic, Decision Structuring Models
  - Analysis: Trend Analysis, What-If Analysis, OLAP, Data Mining
  - Simulation, Optimisation
  - Decision Support Systems: DSS, MIS, EIS
  - Group Decision Support: GDSS, Groupware, CSCW
**Decision-Making**

*Decision:* The choice of one among a number of alternatives

*Decision-Making:* A process of making the choice that includes:
- Assessing the problem
- Collecting and verifying information
- Identifying alternatives
- Anticipating consequences of decisions
- Making the choice using sound and logical judgement based on available information
- Informing others of decision and rationale
- Evaluating decisions

**Decision Sciences** is an interdisciplinary field that draws on economics, forecasting, statistical decision theory, and cognitive psychology. Broadly speaking, Decision Sciences addresses three fundamental and inter-related questions. First, how should a "rational" person make decisions? This question is at the heart of economics, and often serves as a baseline for evaluating human decision making. Second, how do people really make decisions? Recent research has explored the ways in which people are "boundedly rational" and utilize rules-of-thumb and shortcuts to formulate judgements and to choose among alternatives. Often these shortcuts do well, but equally often they lead to systematic biases and serious errors. Finally, given what we know about rational decision making and actual behaviour, how can we help people, especially managers, improve their decision making? Decision researchers employ a variety of techniques to improve decision making, ranging from sharpening statistical intuition to quantitative decision analysis.

**Decision Systems**

- Switching circuits
- Processors
- Computer programs
- Systems for routine DM
- Autonomous agents
- Space probes
**Decision-Making**

- **Decision Sciences**
  - **Normative**
    - Decision Theory
    - Utility Theory (MAUT)
    - Game Theory
    - Theory of Choice
  - **Descriptive**
    - Cognitive Psychology
    - Social and Behavioral Sciences

- **Decision Systems**
  - **Decision Support**

**Decision Support**

**Decision Support: Methods and tools for supporting people involved in the decision-making process**

**Central Disciplines:**
- Operations Research and Management Sciences
- Decision Analysis
- Decision Support Systems

**Contributing and Related Disciplines:**
- Decision Sciences (other than DS itself)
- Statistics, Applied Mathematics
- Computer Sciences (Information Systems, Databases)
- Artificial Intelligence (Expert Systems, ML, NN, GA)
- Knowledge Discovery from Databases and Data Mining

**Operations Research**

- **Operations Research** is concerned with optimal decision making in, and modeling of, deterministic and probabilistic systems that originate from real life
  - OR/MS are the professional disciplines that deal with the application of information technology for informed decision-making
  - OR/MS Professionals aim to provide rational bases for decision making by seeking to understand and structure complex situations and to use this understanding to predict system behavior and improve system performance. Much of this work is done using analytical and numerical techniques to develop and manipulate mathematical and computer models of organizational systems composed of people, machines, and procedures
  - OR/MS draws upon ideas from engineering, management, mathematics, and psychology to contribute to a wide variety of application domains; the field is closely related to several other fields in the "decision sciences" – applied mathematics, computer science, economics, industrial engineering, and systems engineering
Decision Support Systems

**DSS**: Interactive computer-based systems intended to help decision makers utilize data and models to identify and solve problems and make decisions.

**Characteristics:**
- Incorporate both data and models
- Designed to assist managers in semistructured or unstructured decision-making processes
- Support, rather than replace, managerial judgment
- Aimed at improving the effectiveness (rather than efficiency) of decisions

DSS Categories

**MIS**: Management Information System  
**OLTP**: On-Line Transaction Processing  
**DSS**:  
- Data-, Model-, Knowledge-, and Communication-Based  
- DSS Generators  
**EIS**: Executive Information Systems  
**EES**: Executive Support Systems  
**GIS**: Geographic Information Systems  
**GDSS**: Group DSS, Groupware  
**OLAP**: On-Line Analytical Processing (Data Warehouses)  
Distributed Support Systems and Software Agents  
Knowledge Discovery Systems (KDD and Data Mining)  
Expert Systems

What Else is Decision Support?

- Methods and tools for organising data, facts, thoughts, ...  
  - "pencil and paper"  
  - brainstorming  
  - concept mapping, mind mapping  
- Data storage, search and retrieval  
  - Query By Example  
- Representation and visualisation tools  
  - reports  
  - charts  
- Communication technology  
- Mediation systems  
- ...
Decision-Making

Decision Sciences  
- Normative  
- Descriptive

Decision Systems
- Decision Support
  - OR/MS  
  - DA  
  - DSS  
  - Other

- Decision trees  
- Influence diagrams  
- Multi-attribute models

Decision Tables

and

Decision-Making under Uncertainty

Decision-Making Problem

Suppose that one must choose between several uncertain alternatives.

Given:
- Alternatives;
- The consequences of choosing each alternative, described with a single number, e.g. profit / loss in € or aggregated value.

Task: Which alternative to choose?
Working Example

A manufacturing company, faced with a possible increase in demand for its product, considers the following:

**Alternatives:**
1. status quo: no change
2. extend: extending their production line buying a new machine
3. build: building a new production hall with new equipment
4. cooperate: finding additional business partners for production

**Uncertainty involved:**
Market reaction: after the decision, the sales can increase or decrease.

**Consequences:**
Expected profit, shown in decision table on the next slide

Decision Table

**Strict Uncertainty**

<table>
<thead>
<tr>
<th>state</th>
<th>status quo</th>
<th>extend</th>
<th>build</th>
<th>cooperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased sales</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>increased sales</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
</tbody>
</table>

Risk

<table>
<thead>
<tr>
<th>state</th>
<th>probability</th>
<th>status quo</th>
<th>extend</th>
<th>build</th>
<th>cooperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased sales</td>
<td>25%</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>increased sales</td>
<td>75%</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
</tbody>
</table>

Decision Criteria: Strict Uncertainty

<table>
<thead>
<tr>
<th>state</th>
<th>status quo</th>
<th>extend</th>
<th>build</th>
<th>cooperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased sales</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>increased sales</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
<tr>
<td>Pessimist</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>Optimist</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
<tr>
<td>Hurwicz (α=0.3)</td>
<td>28.6</td>
<td>29.6</td>
<td>26.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Laplace</td>
<td>29</td>
<td>33</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Regret</td>
<td>14</td>
<td>6</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>
Risk: Expected (Monetary) Value

Maximise the expected value: \( EV = \sum p(\theta_j) v_j \) 

<table>
<thead>
<tr>
<th>states</th>
<th>probability</th>
<th>status quo</th>
<th>extend</th>
<th>build</th>
<th>cooperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased sales</td>
<td>25%</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>increased sales</td>
<td>75%</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
<tr>
<td>Expected value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>decreased sales</td>
<td>0.25\times 28= 29.5</td>
<td>0.25\times 24= 27.5</td>
<td>0.25\times 16= 16</td>
<td>0.25\times 30= 30</td>
<td></td>
</tr>
<tr>
<td>increased sales</td>
<td>0.75\times 30= 22.5</td>
<td>0.75\times 42= 31.5</td>
<td>0.75\times 44= 33</td>
<td>0.75\times 34= 25.5</td>
<td></td>
</tr>
</tbody>
</table>

Sensitivity Analysis

- Expected value of alternatives vs probability of increased sales
- Stable area
- Expected probability of increased sales (75%)

Decision Analysis
Decision Analysis

**Decision Analysis: Applied Decision Theory**

Provides a framework for analyzing decision problems by
- structuring and breaking them down into more manageable parts,
- explicitly considering the:
  - possible alternatives,
  - available information
  - uncertainties involved, and
  - relevant preferences
- combining these to arrive at optimal (or "sufficiently good") decisions

Evaluation Models

Options

Types of Models in Decision Analysis

Decision Trees

Multi-Attribute Utility Models

Influence Diagrams

Analytic Hierarchy Process
Marko Bohanec

Multi-Attribute Models

cars

- buying
- main
- safety
- doors
- pers
- log

problem decomposition

MARKO

Decision-Making Process

INTELLIGENCE
• Fact Finding
• Problem/Opportunity Sensing
• Analysis/Exploration

DESIGN
• Formulation of Solutions
• Generation of Alternatives
• Modelling/Simulation

CHOICE
• Alternative Selection
• Goal Maximization
• Decision Making
• Implementation

The Decision Analysis Process

Identify decision situation and understand objectives
Identify alternatives
Decompose and model
• problem structure
• uncertainty
• preferences
Sensitivity Analyses
Choose best alternative
Implement Decision
Decision Analysis: Related Disciplines

- **DSS, GDSS**
  - Group Decision Process

- **ES, ML**
  - Qualitative Multi-Attribute Models

**Multi-Criteria Optimisation**
- Risk Analysis and Simulation
- Bayesian Networks
- Markov Modelling

- Decision Trees
- Influence Diagrams
- Multi-Attribute Utility Models
- Analytic Hierarchy Process

### Working Example

**Decision table (Payoff matrix)**

<table>
<thead>
<tr>
<th>alternative</th>
<th>status quo</th>
<th>extend</th>
<th>build</th>
<th>cooperate</th>
</tr>
</thead>
<tbody>
<tr>
<td>decreased sales</td>
<td>28</td>
<td>24</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>increased sales</td>
<td>30</td>
<td>42</td>
<td>44</td>
<td>34</td>
</tr>
</tbody>
</table>
Working Example

Equivalent decision tree:

Expected profit

status quo

attend

build

cooperate

Decision Tree

Different from decision trees used in Machine Learning:
• different types of nodes
• always drawn horizontally, from left to right
• "hand-crafted", not learned from data

Decision tree represents the decision problem in terms of chains of consecutive decisions and chance events.

Time proceeds from left to right.

Uncertainties associated with chance events are modelled by probabilities.

Components of Decision Trees

Decision node: represents alternatives

Chance Node: represents events (states of nature)

Terminal (End) Node: represents consequences of decisions
Solving Decision Trees

From right to left:

\[ EV = \max_i EV_i \text{ [maximize profit]} \]

or

\[ EV = \min_i EV_i \text{ [minimise losses]} \]

\[ EV = \sum_i p_i EV_i \]

\[ EV = \text{Value} \]

Solved Decision Tree

<table>
<thead>
<tr>
<th>alternatives</th>
<th>events</th>
<th>expected profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>status quo</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>extend</td>
<td>decreased sales (0.25)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>increased sales (0.75)</td>
<td>24</td>
</tr>
<tr>
<td>build</td>
<td>decreased sales (0.25)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>increased sales (0.75)</td>
<td>44</td>
</tr>
<tr>
<td>cooperate</td>
<td>decreased sales (0.25)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>increased sales (0.75)</td>
<td>34</td>
</tr>
</tbody>
</table>

Decision Tree Development

1. Place decision and chance nodes in a logical time order
2. Independent chance nodes can be placed in any order
3. Estimate probabilities of all chance events
4. The sum of probabilities in a chance node must be 1
5. In terminal nodes, specify consequences by a single performance measure, e.g.:
   - money,
   - aggregate utility or
   - results of a multiple criteria analysis
Decision Analysis Software

http://decision-analysis.society.informs.org/Field/FieldSoftware.html

See also:
OR/MS Today, December 2006
http://www.lionhrtpub.com/orms/surveys/das/das.html

Decision Tree Software

Add-Ins for Microsoft Excel:
- TreePlan: http://www.treeplan.com/
- PrecisionTree: http://www.palisade-europe.com/precisiontree/

Decision-Tree Development Programs:
- TreeAge Pro (DATA): http://www.treeage.com/
- DecisionPro: http://www.vanguardsw.com/
- DPL: http://www.syncopationsoftware.com/

TreePlan
Working Example

Decision tree:

- Alternatives: status quo, extend, build, cooperate
- Events (states): decreased sales (0.25), increased sales (0.75)
- Expected profit:
  - Decreased sales: (28, 30, 24, 16, 12)
  - Increased sales: (30, 42, 44, 34, 30)

Motivation for Influence Diagrams

Decision trees:
- Sometimes too detailed,
- Grow exponentially,
- Contain repeated information.

Only three different elements:

Working Example

Equivalent Influence diagram:
Influence Diagram

Influence diagram is a:
• high-level (compact),
• visual representation,
• displaying relationships between essential elements that affect the decision.

Two levels of detail:
• higher: only elements and relations
• lower: detailed information defined with each element

Elements of Influence Diagrams

Decision node:
represents alternatives

Chance Node:
represents events (states of nature)

Value Node represents:
• consequences
• objectives, or
• calculations

Arcs in Influence Diagrams

- Decision A affects the probabilities of event B; Decision A is relevant for event B
- The outcome of event A affects the probabilities of event B; Event A is relevant for event B
- Decision A occurs before decision B; Decisions A and B are sequential
- Decision B occurs after event A; The outcome of A is known when deciding about B
Example 1: Building a Plant

- Number of Cars
- Industry Growth
- Pollution Level
- New Plant Licensed
- New Regulations
- Build New Plant?
- Plant Profit

Example 2: Evacuation Decision (1/2)

- Will hit
- Will miss
- Evacuate
- Stay
- Forecast
- Hurricane Path
- Hits
- Misses
- Decision
- Consequences
- Decision table: Decision | H. Path

Example 2: Evacuation Decision (2/2)

- Forecast
- Hurricane Path
- Evacuate?
- Consequences
- Decision table: Decision | H. Path | Wait
- What for Forecast?
Influence Diagram Software

Add-Ins for Microsoft Excel:
- PrecisionTree: [http://www.palisade-europe.com/precisiontree/](http://www.palisade-europe.com/precisiontree/)

Influence-Diagram Development Programs:
- GeNIe: [http://genie.sis.pitt.edu/](http://genie.sis.pitt.edu/)
- Analytica: [http://www.lumina.com/ana/whatisanalytica.htm](http://www.lumina.com/ana/whatisanalytica.htm)
Multi-Attribute Models

Motivation for Multi-Attribute Modeling

So far we have considered single-objective models, but most of real-life decisions are multiple-objective: e.g., price + performance (conflicting).

Influence diagrams facilitate multi-objective modeling to some degree. However, more is needed in terms of model development and analysis of decisions. Thus, specialised models and software.

Multi-attribute modeling is very useful and practical.

ID’s and Multiple Objectives

Invest? Venture succeeds or fails
Return on investment Computer Industry Growth
Overall Satisfaction
Maximize Overall Satisfaction
Return on Investment Invest in Computer Industry
Multi-Attribute Models

Digital photo camera

Multi-attribute model

Evaluation of cameras

Multi-Attribute Model Structure

Utility

Utility function

Attributes

Options

Multi-Attribute Model for Car Selection

Car

Utility

Utility function

Attributes

Cars
Quantitative Multi-Attribute Model for Car Selection

Utility Function

\[ 50 \times P_1 + 20 \times P_2 + 30 \times P_3 \]

Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Price</th>
<th>Fuel</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22,000</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>26,000</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>19,000</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Qualitative Multi-Attribute Model for Car Selection

Utility Function

Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Price</th>
<th>Fuel</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>med</td>
<td>high</td>
<td>acc</td>
</tr>
<tr>
<td>2</td>
<td>high</td>
<td>low</td>
<td>good</td>
</tr>
<tr>
<td>3</td>
<td>low</td>
<td>med</td>
<td>acc</td>
</tr>
</tbody>
</table>

Hierarchical Multi-Attribute Model

Utility function

Aggregate attributes

Basic attributes

Alternative
Questions

1. Have you ever encountered a:
   - multi-objective decision problem?
   - multi-attribute model?

   When, where, for what kind of problems?

2. Compare multi-attribute models with:
   - decision trees
   - influence diagrams

3. Suggest types of decision problems suitable for the application of multi-attribute models

Multi-Attribute Modelling: Why?

- Systematic, structured approach (to difficult real-life problems)
- Model development:
  - problem decomposition into smaller, less-complex subproblems
  - requires understanding and careful elaboration of the problem
  - facilitates and motivates communication and knowledge interchange
- Evaluation:
  - selection of a single option
  - option ranking
- Analysis:
  - "what-if" analysis
  - sensitivity analysis
  - explanation:
    - how? (evaluation procedure)
    - why? (selective explanation of advantages/disadvantages)
  - option generation
- Contributes to better decisions:
  - understanding, justification, explanation, documentation

Multi-Attribute Modelling: How?

0. Problem identification
1. Tree (or hierarchy) of attributes
2. Utility functions
3. Evaluation and analysis of alternatives
4+ Implementation
1. Tree of Attributes

Decomposition of the problem to to sub-problems ("Divide and Conquer")

The most difficult stage!

2. Utility Functions (Aggregation)

Aggregation: bottom-up aggregation of attributes' values

3. Evaluation and Analysis

- direction: bottom-up
- (terminal ⇒ root attributes)
- result: each option evaluated
- inaccurate/uncertain data?
3. Evaluation and Analysis

- interactive inspection
- "what-if" analysis
- sensitivity analysis
- explanation

MADM Tools

1. “Paper and Pencil” (Abacon)
2. Spreadsheets and mathematical modelling software (MS Excel)
3. Specialized MADM software

Spreadsheet Modelling
A simple computer program for MADM that facilitates:

- Creation and editing of
  - model structure (tree of attributes)
  - value scales of attributes
  - decision rules (incl. using weights)
  - options and their descriptions (data)
- Evaluation of options (can handle missing values)
- Presentation of evaluation results with:
  - tables
  - charts
- "What-if" analysis
- Preparing a report
Some Application Areas

1. INFORMATION TECHNOLOGY
   - evaluation of computers
   - evaluation of software
   - evaluation of Web portals

2. PROJECTS
   - evaluation of projects
   - evaluation of proposal and investments
   - product portfolio evaluation

3. COMPANIES
   - business partner selection
   - performance evaluation of companies

4. PERSONNEL MANAGEMENT
   - personnel evaluation
   - selection and composition of expert groups
   - evaluation of personal applications

5. MEDICINE and HEALTH-CARE
   - risk assessment
   - diagnosis and prognosis

6. OTHER AREAS
   - assessment of technologies
   - assessments in ecology and environment
   - granting personal/corporate loans

Allocation of Housing Loans

- Housing Fund of the Republic of Slovenia:
  Allocation of housing loans to citizens and non-profit organizations
- Since 1991: 21 completed floats of loans for citizens (recurring decision problem)
- Management decision support system for housing loan allocation
- Evaluation of loan priority: qualitative multi-attribute decision models (DEX)
- 2/3 of housing loans in Slovenia are allocated in this way

Evaluation of R&D Projects
Slovenian Ministry of Science and Technology


Evaluation of R&D Projects
Multi-Attribute Model Structure (partial)

Evaluation of R&D Projects
Evaluation of projects in 1992:
516 projects: 1094 reviews contributed by 90 reviewers
Breast Cancer Risk Assessment

- Hormonal circumstances
- Personal characteristics
- Other

Menstrual cycle

1. average R-28
2. long R-28
3. long R29+
4. long N
5. short R-28
6. average R29+
7. short N
8. average N

Menopausal duration

- Fertility
- Age
- Oral contraceptives
- Personal characteristics
- Cancerogenic exposure
- Demographical circumst.

Average Importance of Attributes

<table>
<thead>
<tr>
<th>Attribute Category</th>
<th>Regression</th>
<th>Entropy</th>
<th>Use Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menstrual cycle</td>
<td>125</td>
<td>123</td>
<td>110</td>
</tr>
<tr>
<td>Age</td>
<td>175</td>
<td>126</td>
<td>145</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>65</td>
<td>76</td>
<td>41</td>
</tr>
<tr>
<td>Personal characteristics</td>
<td>58</td>
<td>56</td>
<td>39</td>
</tr>
<tr>
<td>Cancerogenic exposure</td>
<td>290</td>
<td>188</td>
<td>179</td>
</tr>
<tr>
<td>Demographical circumst.</td>
<td>40</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td>Other</td>
<td>55</td>
<td>42</td>
<td>27</td>
</tr>
</tbody>
</table>
Evaluation and Analysis of Options

<table>
<thead>
<tr>
<th>Option/Condition</th>
<th>Whole evaluation</th>
<th>Missing data</th>
<th>What-if analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menstrual cycle</td>
<td>moderate risk</td>
<td>average</td>
<td>moderate risk</td>
</tr>
<tr>
<td>Fertility duration</td>
<td>average</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>Age</td>
<td>over 40</td>
<td>up to 40</td>
<td>moderate risk</td>
</tr>
<tr>
<td>Reg./stab. menstruation</td>
<td>R29+</td>
<td>R29+</td>
<td>R29+</td>
</tr>
<tr>
<td>Fertility</td>
<td>moderate risk</td>
<td>moderate risk</td>
<td>moderate risk</td>
</tr>
<tr>
<td>Menopause</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Personal characteristics</td>
<td>high risk</td>
<td>high risk</td>
<td>high risk</td>
</tr>
<tr>
<td>Physical activity</td>
<td>higher</td>
<td>higher</td>
<td>higher</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Demographical circumstances</td>
<td>high risk</td>
<td>moderate risk</td>
<td>moderate risk</td>
</tr>
</tbody>
</table>

Selective Explanation of Options

<table>
<thead>
<tr>
<th>Reason FOR higher risk</th>
<th>Reason AGAINST higher risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age over 40</td>
<td>Personal characteristics</td>
</tr>
<tr>
<td>Quetel's index 29+</td>
<td>Family history no</td>
</tr>
<tr>
<td>Cancerogenic exposure high risk</td>
<td>Menopause no</td>
</tr>
<tr>
<td>First delivery 29 or younger</td>
<td>Physical factors higher</td>
</tr>
<tr>
<td>Oral contraceptives no</td>
<td>Demographical circumstances high risk</td>
</tr>
</tbody>
</table>

Diabetic Foot Risk Assessment

Who:
- General Hospital Novo Mesto, Slovenia
- IJS
- Infonet, d.o.o.

Why:
- Reduce the number of amputations
- Improve the risk assessment methodology
- Improve the DSS module of clinical information system

How:
- Develop multi-attribute risk assessment model
- Evaluate it on patient data (about 3400 patients)
- Integrate into the clinical information system

Diabetic Foot Risk Assessment

Risk Assessment Model

- History
- Present status
- Tests
  - Ulcers
  - Amputations
  - Symptoms
  - Other changes
  - Environmental

Environmental: Clay-Pit Location


Clay-Pit Location Model

- SITE SUITAB
  - ENVIRONMENT
    - ATTRACT
  - FEASIBILITY
    - VULNERAB
    - SOC-PSYCH
    - TECHN
    - ECONOM
      - Indirect
      - Direct
  - LAND USE
  - POLLUTION
  - VALUATION
  - LAND ORG

Legend:
1 Bukovnik
2 Margetnca
3 Existing clay-pit
4 Okroglica
Brick factory

Clay-Pit Location Evaluation

Environmental: Location of a Radioactive Waste Repository

Advising Children in Choosing Sports

Talent:
- A knowledge-based computer program
- for advising children in choosing sports
- in primary and secondary schools
Database of Measurements

GENERAL DATA
- Age
- Gender
- Date of measurement

MORPHOLOGICAL TESTS
- BH: Body height (cm)
- BW: Body weight (kg)
- SF: Skin fold of the upper arm (mm)

MOTORIC TESTS
- TAP: Taping with hand (number)
- SJ: Standing jump (cm)
- PB: Pylon jump backward (s)
- SU: Sit up of the trunk (number)
- DB: Deep bend on bench (cm)
- LEAF: Bent arm hang on horizontal bar (s)
- 800m: 800 m sprint (s)
- 1500m: 1500 m run (s)

Talent: Basics

EVALUATION by sport disciplines

MULTIATTRIBUTE EVALUATION MODELS

“SPORTS-CARD” MEASUREMENT
3 morphological and 6 motoric tests

Evaluation Models

23 disciplines:
- Athletics (5 disciplines)
- Swimming (4)
- Skiing (3)
- Football
- Volleyball
- Handball
- Tennis
- Badminton

Marko Bohanec
Evaluation Model Structure

Evaluation and Explanation

Banks @ SI Housing Schema

Who:
- Slovenian Housing Fund
- IJS
- Temida

What:
- Evaluate and select banks for SHS
- Distribute rights for loan allocation to banks

Why:
- Difficult and sensitive decision problem

How:
- Combined quantitative/qualitative modelling

Assessment of Governmental Life-Event Portals

<table>
<thead>
<tr>
<th>State/Land</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td></td>
</tr>
<tr>
<td>Italy:</td>
<td><a href="http://www.italia.gov.it">http://www.italia.gov.it</a></td>
</tr>
<tr>
<td>Spain:</td>
<td><a href="http://www.administracion.es">http://www.administracion.es</a></td>
</tr>
<tr>
<td>Great Britain:</td>
<td>UKonline <a href="http://www.ukonline.gov.uk">http://www.ukonline.gov.uk</a></td>
</tr>
<tr>
<td>Austria:</td>
<td>Internet Service HELP <a href="http://www.help.gv.at">http://www.help.gv.at</a></td>
</tr>
<tr>
<td>Bremen (Germany):</td>
<td>Bremer-online-service <a href="http://www.bremer-online-service.de">http://www.bremer-online-service.de</a></td>
</tr>
<tr>
<td>Rest of the world</td>
<td></td>
</tr>
<tr>
<td>Canada:</td>
<td>Government of Canada <a href="http://canada.gc.ca">http://canada.gc.ca</a></td>
</tr>
<tr>
<td>Hong Kong:</td>
<td>Government Services <a href="http://www.info.gov.hk/eindex.htm">http://www.info.gov.hk/eindex.htm</a></td>
</tr>
</tbody>
</table>

Life-Event Portals
Structure of Models

- Qualitative models for assessing life-event portals at three levels
  - Evaluation of LE portals as a whole
  - Evaluation of life-events
  - Evaluation of e-services
Life-Event Portals
Assessment of Portals in 2002/2003

Genetically-Modified Crops
ECOGEN
Soil ecological and economic evaluation of genetically modified crops
QLK5-CT-2002-01666 2003-2006
http://www.ecogen.dk/

SIGMEA
Sustainable introduction of genetically modified crops into European agriculture
FP6-SSP1-2002-502981 2004-2006
http://sigmea.dyndns.org/

ECOGEN and SIGMEA Models
Evaluating cropping systems in terms of ecology, coexistence and economy
ECOGEN and SIGMEA Models

1. "Grignon" model
   Economic and ecological assessment of GM maize cropping systems

2. ESQI: ECOGEN Soil Quality Model
   Assessing the impact of cropping systems on soil quality

3. SMAC Advisor: SIGMEA Maize Coexistence
   Decision support software
   Assessing maize coexistence

"Grignon" Model
Model Output: Topmost Levels

"Grignon" Model
Model Input: Cropping System
Some Results

All the options have the same soil quality value of 3.

The use of Bt-maize in Foulum positively affects Soil functioning (with ploughing) and Soil diversity (when using minimum tillage).

Minimum tillage positively affects nematodes richness, Detritivorous mesofauna and Protozoa biomass, leading to better Activity.

Bt-maize reduces Protozoa biomass, but improves Comminution due to Anecic earthworm biomass.

At Varois and Narbons, Bt-maize reduced many faunal populations without affecting the higher level outcomes of Soil functioning, diversity or quality.
Decision Problem

Problem:
Can GM maize be grown in coexistence with plants on other fields?

Criterion:
Genetic interference (Adventitious Presence)
Typical target AP: 0.9%
Factors:
pollen flow, volunteers, feral plants, mixing during harvesting, transport, storage and processing, human error, accidents, ...

SMAC Advisor

Decision support software that assesses the achievable AP given:
• relation between fields: distance, relative size, wind direction, etc.
• type and characteristics of used seeds
• environmental characteristics (e.g., background GM pollen pressure),
• use of machinery (e.g., sharing with other farmers)
• target AP

... and gives recommendations:
- farming allowed
- farming disallowed
- assess risks (coexistence is possibly achievable)
- assess additional measures (coexistence achievable by small changes)

ESQI Web Page
http://ai.ijs.si/MarkoBohanec/ESQI/ESQI.php
Summary of Applications

1. Loan Allocation
2. Evaluation/Selection of Projects
3. Medicine: Risk Assessment
4. Evaluation/Selection of Locations
5. Advising in Sports
6. Application ranking (in Housing)
7. Business partner selection (in Housing)
8. Assessment of Life-Event Portals
9. Assessment of Cropping Systems

Other areas:
- evaluation of technology (cars, computers, software, Web pages and services, ...)
- evaluation of investment proposals, tenders
- production portfolio evaluation
- performance evaluation of companies
- personnel management