HINT:
Learning DEXi Models From Data

Introduction

- Multi-Attribute Decision Making:
  - decompose the problem to less complex sub-problems

- DEX:
  An Expert System Shell for MADAM
  - goal level attributes
  - decision rules

Problem

Development of hierarchical decision models is difficult

Given decision examples taken from
- existing database of past decisions or
- provided explicitly by decision-maker;

develop a corresponding model (hierarchy + functions)
Example

- What is the result of "regional" decision-tree learning, such as See5?
- How does this table look in DEX?
- How to create a hierarchical DEX model from this table?

Decision Tree (See5)

DExi Table & Rules

Scales

Attribute Scale
- X1: lo, med, hi
- X2: lo, med, hi
- X3: lo, med, hi

Tables

<table>
<thead>
<tr>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>lo</td>
<td>lo</td>
<td>lo</td>
<td>lo</td>
</tr>
<tr>
<td>lo</td>
<td>med</td>
<td>lo</td>
<td>lo</td>
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<tr>
<td>lo</td>
<td>med</td>
<td>hi</td>
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<tr>
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<td>hi</td>
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</tr>
</tbody>
</table>

Average weights
Example

<table>
<thead>
<tr>
<th>x1</th>
<th>x2</th>
<th>x3</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>lo</td>
<td>lo</td>
<td>lo</td>
<td>lo</td>
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<tr>
<td>lo</td>
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<td>lo</td>
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<td>hi</td>
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<td>hi</td>
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</tr>
<tr>
<td>hi</td>
<td>lo</td>
<td>lo</td>
<td>hi</td>
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<tr>
<td>hi</td>
<td>hi</td>
<td>lo</td>
<td>hi</td>
</tr>
</tbody>
</table>

- What is the result of "regional" decision-tree learning, such as See5?
- How does this table look in DEK?
- How to create a hierarchical DEK model from this table?

Boolean Function Decomposition

Decomposition

Implementation

Decomposition method

Extended Ashenhus-Curfs decomposition of Boolean functions:
- Adapted to develop plots in multi-attribute decision models
- Multi-valued attributes
- Relation and soft and soft and soft programming
- Partition selection measures
- Generalization

Restrictions:
- Multiple attributes and utility

Implementation:
- HiNT: Hierarchical Induction Tool in C++
Single-step decomposition

<table>
<thead>
<tr>
<th>$y_1$</th>
<th>$y_2$</th>
<th>$y_3$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>lo</td>
<td>lo</td>
<td>lo</td>
</tr>
<tr>
<td>lo</td>
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<td>lo</td>
<td>lo</td>
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<tr>
<td>lo</td>
<td>med</td>
<td>hi</td>
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<tr>
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<td>hi</td>
<td>lo</td>
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<tr>
<td>med</td>
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<td>med</td>
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<tr>
<td>med</td>
<td>hi</td>
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<td>hi</td>
</tr>
<tr>
<td>hi</td>
<td>hi</td>
<td>lo</td>
<td>hi</td>
</tr>
</tbody>
</table>

$x_1, x_2, x_3$

Partition matrix

$y = F(x_1, x_2, x_3)$

<table>
<thead>
<tr>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>lo</td>
<td>lo</td>
<td>lo</td>
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<tr>
<td>med</td>
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<td>med</td>
<td>hi</td>
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</tr>
<tr>
<td>hi</td>
<td>hi</td>
<td>lo</td>
<td>hi</td>
</tr>
</tbody>
</table>

$y = G(x_1, x_3)$

Column compatibility

$y = H(x_1, x_3)$

compatible columns

incompatible columns
Single-step decomposition

- reduced complexity
- consistency
- generalization

Candidate decompositions

HINT Implementation: In ORANGE

http://magix.fri.uni-lj.si/orange/doc/modules/orngC1.htm
Application: Housing Loan Allocation

- **User**: Housing Fund of the Republic of Slovenia
- **Task**: Allocating available funds to applicants for housing loans
- **Method**: Using a multi-attribute model for priority evaluation of applications
- **Supported by a DSS since 1991**:
  - Completed float of loans 21
  - Applications: 44378 received, 27813 approved
  - Allocated loans: 354 m in € (2/3 of housing loans in Slovenia)

Modes of Operation

1. **DEX only**: from expertise
2. **HINT only**: from data
3. **Supervised**: from data under expert supervision
4. **Serial**: HINT-developed model subsequently refined by the expert
5. **Parallel**: parallel development of model(s) by DEX and HINT
6. **Combined**: combining sub-models developed in different ways

1. **DEX-Only Mode**

![Diagram showing the DEX-Only Mode of Operation]

<table>
<thead>
<tr>
<th>Housing Status</th>
<th>Soc-Health Status</th>
<th>Soc-Health Priority</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Low</td>
<td>Low</td>
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</table>
2. HINT-Only Mode (1 of 2)

Reconstruction of the original model from unstructured data:
- Real-life data from one foaf in 1994
- 1932 applications
- 12 attributes (2 to 5 values)
- 722 unique examples
- 3.7% coverage of the attribute space
- Unsupervised decomposition

2. HINT-Only Mode (2 of 2)

Results:
- Relatively good overall structure
- Inappropriate structure around c.3
- Excellent classification accuracy:
  - HINT: 947 ± 2.5%
  - C4.5: 859 ± 3.9%

3. Supervised Mode (1 of 4)

Unstructured dataset:

Redundant: cult_hist, fin_sources
3. Supervised Mode (2 of 4)

All partitions with h=3 and minimal v (v=3) [11 of 120]

- suitab
- advantage
- employed
- marriage
- employed
- family
- advantage
- stage
- employed
- marriage
- children
- health
- health
- family
- earnings
- employed
- children
- status
- housing
- age

New concept: status

3. Supervised Mode (3 of 4)

All partitions with h=3 and minimal v (v=4) [3 of 56]

- ownership
- suitab
- advantage
- stage
- social
- health
- family
- age

New concepts: social and then present

3. Supervised Mode (4 of 4)

Final structure

Results:
- Expert satisfied with the structure
- Improved classification accuracy:
  - supervised: 37.8 ± 4.8%
  - unsupervised: 94.7 ± 2.5%
4. Serial Mode

1. Develop an initial model by HINT from data
2. Extend/enhance the model "manually" using DEX

For example:
1. Take the model developed by HINT in supervised mode
2. Add the attributes <cult-hist and fin-sources>
   - Extend the model structure
   - Or fit the corresponding decision rules

5. Parallel Mode

Develop two or more independent models by HINT and DEX for:
- comparison
- "second opinion"
- feasibility

For example, in this research we developed:
1. one DEX model
2. two HINT models: in supervised and unsupervised mode

6. Combined Mode

Develop a single model using sub-models developed
- by different methods and
- from different sources

Hypothetical example:
1. Develop <status by HINT
2. Develop <job-health by HINT from a different data set
3. A real-estate expert develops the <house subtree using DEX
4. All three model is "glued" together in DEX by a loan-allocation expert
HINT: Conclusion

- Integration of DM and DS for model-based problem solving
- Requirements
  - common module representation
  - expertise and data (possibly partial)
  - methods for "as a model" (MDS) and "as an aid" (GMD) model development
- Offers a multitude of method combinations:
  - independent serial, parallel, combined, ...
- Specific schemes:
  - qualitative hierarchical multi-attribute models
  - DEX as a GMD method
  - HINT as a DM Method

Weak points and limitations:
- HINT requires substantial coverage of attribute space
- qualitative attributes only
- very sensitive to noise in data
- high time complexity