Features of the Expert-System-Shell SPIRIT

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Overview

Knowledge processing in SPIRIT
Reliability of answers
Graphs and hypergraphs
Recall by a stimulus
Conclusion and remarks
Knowledge processing in SPIRIT

Step 1: Definition of a knowledge domain

Specify variables $V_l$ with respective values $v_l$; Literal $V_l = v_l$
e.g.: MARITAL=single, STUDENT=true.
Propositions formed by junctors $\land$ (and), $\lor$ (or), $\neg$ (not),
Denoted by $A,B,C \Rightarrow$ Propositional language $L$.
Extension to conditional language $L|L$ by binary conditional operator $|$
e.g.: MARITAL=single $| (STUDENT=true \land PARENT=true)$.
$B|A [x], A, B \in L, x \in [0;1]$. 
Excursus
Step 2: Knowledge acquisition

Given
set of rules
\( R = \{B_i|A_i [x_i], i=1,\ldots,I\} \).

Adaption of uniform distribution \( P^0 \) to \( R \) by solving
\[
P^* = \arg \min R(Q, P^0), \quad \text{s.t. } Q \models R
\]  \tag{1}
\( R(Q, P^0) \) relative entropy from \( P^0 \) to \( Q \).
Excursus
Step 3: Inference

Focus
\[ \mathbf{E} = \{D_j | C_j [y_j], j=1,\ldots,J\}. \]

Adaption of \( P^* \) to \( \mathbf{E} \) by solving
\[
P^{**} = \arg \min R(Q, P^*), \quad \text{s.t. } Q \models \mathbf{E}. \tag{2}
\]

Query: \( H|G \)

Answer \( P^{**}(H|G) \).
Excursus

CII 04
Reliability of answers

Given
\[ P^* = \arg \min P (Q, P^0), \quad \text{s.t. } Q \models R \] \hspace{1cm} (1)

\[ H \mid G = ? \]

Lower bound
\[ \bar{u} = \min Q (H \mid G) \quad \text{s.t. } Q \models R \quad \text{and} \]

Upper bound
\[ \bar{u} = \max Q (H \mid G) \quad \text{s.t. } Q \models R. \]

Second order uncertainty of \( H \mid G \)
\[ m = -\text{ld} \bar{u} - (-\text{ld} \bar{u}) \text{ [bit].} \]
### Excursus

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Database</th>
<th>Bayes</th>
<th>Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset</td>
<td></td>
<td></td>
<td>FO</td>
</tr>
<tr>
<td>Save knowledge to buffer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restore knowledge from buffer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delete buffer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restore from previous iteration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compute expected utilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compute current information gap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assign actual probabilities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Rule Table

<table>
<thead>
<tr>
<th>Act</th>
<th>Index</th>
<th>P act</th>
<th>Rule text</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0,3000</td>
<td>STUDENT</td>
<td>YOUNG</td>
</tr>
<tr>
<td>1</td>
<td>0,9000</td>
<td>YOUNG</td>
<td>STUDENT</td>
</tr>
<tr>
<td>2</td>
<td>0,7000</td>
<td>YOUNG</td>
<td>MARITAL=s</td>
</tr>
<tr>
<td>3</td>
<td>0,8000</td>
<td>YOUNG</td>
<td>MARITAL=c</td>
</tr>
<tr>
<td>4</td>
<td>0,1000</td>
<td>MARITAL=s</td>
<td>(STUDENT∧ PARENT)</td>
</tr>
<tr>
<td>5</td>
<td>0,8000</td>
<td>MARITAL=s</td>
<td>YOUNG</td>
</tr>
</tbody>
</table>

- Act: 0,3000
- Index: 0
- P act: 0.3000
- Rule text: STUDENT | YOUNG

- Act: 0,9000
- Index: 0
- P act: 0.9000
- Rule text: YOUNG | STUDENT

- Act: 0,7000
- Index: 0
- P act: 0.7000
- Rule text: YOUNG | MARITAL=s

- Act: 0,8000
- Index: 0
- P act: 0.8000
- Rule text: YOUNG | MARITAL=c

- Act: 0,1000
- Index: 0
- P act: 0.1000
- Rule text: MARITAL=s | (STUDENT∧ PARENT)

- Act: 0,8000
- Index: 0
- P act: 0.8000
- Rule text: MARITAL=s | YOUNG

- Act: 0,2250
- Index: 0
- P act: 0.2250
- Rule text: PARENT | STUDENT

**Pmin: 0.0 Pmax: 0.999 l-gap: 26.5754 bit**

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**SPIRIT**

CII 04
Graphs and hypergraphs

Example creditworthiness

NB: No Bad earlier credits (t/f)
KN: client in KNown to the bank (t/f)
IN: INcome sufficient (t/f)
IA: Inquiry Agency (t/f)
GO: GOod credits (yes/no)

SU: somebody offers SUREty (t/f)
ME: financial MEAns available (t/f)
JO: JOB for more than 3 years (t/f)
LO: LOan the money (t/f)
U: RetURN of investment.

<table>
<thead>
<tr>
<th>Index</th>
<th>P act</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,87998</td>
<td>GO=yes</td>
</tr>
<tr>
<td>1,70000</td>
<td>SU</td>
</tr>
<tr>
<td>2,05100</td>
<td>SU</td>
</tr>
<tr>
<td>3,65984</td>
<td>(IA ∧ KN)</td>
</tr>
<tr>
<td>4,39466</td>
<td>(IA ∧ KN)</td>
</tr>
<tr>
<td>5,10000</td>
<td>(∼IA ∧ ∼KN)</td>
</tr>
<tr>
<td>6,34832</td>
<td>(∼IA ∧ ∼KN)</td>
</tr>
<tr>
<td>7,23980</td>
<td>(IA ∧ ∼KN)</td>
</tr>
<tr>
<td>8,22119</td>
<td>(IA ∧ ∼KN)</td>
</tr>
<tr>
<td>9,15005</td>
<td>(KN ∧ NB ∧ ME)</td>
</tr>
<tr>
<td>10,06011</td>
<td>(KN ∧ NB ∧ ME)</td>
</tr>
<tr>
<td>11,011007</td>
<td>(KN ∧ NB ∧ ME)</td>
</tr>
<tr>
<td>12,05010</td>
<td>(KN ∧ NB ∧ ME)</td>
</tr>
<tr>
<td>13,020112</td>
<td>(KN ∧ NB ∧ ∼ME)</td>
</tr>
<tr>
<td>14,016020</td>
<td>(KN ∧ NB ∧ ∼ME)</td>
</tr>
</tbody>
</table>

15,0,19997 (KN ∧ NB ∧ ∼ME) | GO=yes
16,0,16009 (KN ∧ NB ∧ ∼ME) | GO=no
17,0,18002 (∼KN ∧ NB ∧ ME) | GO=yes
18,0,21050 (∼KN ∧ NB ∧ ME) | GO=no
19,0,43001 (IN ∧ ME) | GO=yes
20,0,33821 (IN ∧ ME) | GO=no
21,0,25006 (IN ∧ ME) | GO=yes
22,0,19322 (IN ∧ ME) | GO=no
23,0,24991 (∼IN ∧ ∼ME) | GO=yes
24,0,34298 (∼IN ∧ ∼ME) | GO=no
25,0,59000 JO | GO=yes
26,0,53000 JO | GO=no
27,1,00000 U=1466 | (LO∧yes ∧ GO=yes)
28,1,00000 U=8614 | (LO∧yes ∧ GO=no)
29,1,00000 U=0 | (LO∧no ∧ GO=no)
30,1,00000 U=29 | (LO∧no ∧ GO=yes)
Graphs and hypergraphs

Markov net

Given

set of finite valued variables \( V = \{V_1, \ldots, V_L\} \).

With respect to \((V;P)\) if for any variable \( V_l, V_m: \)
\[(V_l, V_m) \notin E \iff (V_l \perp V_m \mid V \setminus \{l,m\}; P).\]

\(\Rightarrow\) Minimal independency graph
Graphs and hypergraphs

Inference net

Given
set of finite valued variables $V = \{V_1, \ldots, V_L\}$.

Variables $V_l$ and $V_m$ are involved in a rule $B_i|A_i$

$V_l$ and $V_m$ connected by an arrow, if a value $v_l$
involved in $A_i$ and $v_m$ in $B_i$.

$V_l$ and $V_m$ connected by an edge, if $v_l$ and $v_m$ appear
in the conclusion $B_i$ of the same rule.
Excursus
Hypertree

Given
set of finite valued variables $V = \{V_1, \ldots, V_L\}$.
Denote $E_i(B_i|A_i) \subseteq V$ set of variables involved in a rule $B_i|A_i$
$\Rightarrow E_i$ hyperedges of the hypergraph $(V, \mathcal{E})$.

In general $(V, \mathcal{E})$ not acyclic,
use “fill-in”-methods to construct (acyclic) hypertree

For propagation: Hypertree $\Rightarrow$ junctiontree (each node
corresponds to an edge of the hypertree)
Excursus
Graphs and hypergraphs

### Application credit worthiness

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>No Bad earlier credits</td>
<td>true</td>
</tr>
<tr>
<td>KN</td>
<td>client in KNown to the bank</td>
<td>true</td>
</tr>
<tr>
<td>JO</td>
<td>JOb for more than 3 years (t/f)</td>
<td>false</td>
</tr>
<tr>
<td>SU</td>
<td>somebody offers SUrety (t/f)</td>
<td>false</td>
</tr>
<tr>
<td>ME</td>
<td>financial MEans available (t/f)</td>
<td>true</td>
</tr>
<tr>
<td>IN</td>
<td>INcome sufficient (t/f)</td>
<td>true</td>
</tr>
<tr>
<td>IA</td>
<td>Inquiry Agency (t/f)</td>
<td>true</td>
</tr>
<tr>
<td>LO</td>
<td>LOan the money (t/f)</td>
<td>yes</td>
</tr>
<tr>
<td>GO</td>
<td>GOod credits (yes/no)</td>
<td>yes</td>
</tr>
</tbody>
</table>

- Amount of credits: 10,000 €
- Credit’s lifespan: 4 years
- U = 723,06 €
Excursus
Recall by a stimulus

\[ V_i \in \{V_1, \ldots, V_L\}, \]

\( P^* \) epistemic state.

\( P^{**} \) adaption of \( P^* \) to a certain focus \( \mathbf{E} = \{F[1]\} \).

Impact measure: \( R((V_i; P^{**}),(V_i; P^*)) \) [bit].
Excursus
Excursus
## Conclusion and remarks

<table>
<thead>
<tr>
<th>Model</th>
<th>no. variables</th>
<th>no. rules</th>
<th>no. LEGs</th>
<th>$H(P^0)$</th>
<th>$H(P^*)$</th>
<th>utility yes/no</th>
<th>decision yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>20</td>
<td>340</td>
<td>17</td>
<td>29.91</td>
<td>18.57</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>TS</td>
<td>76</td>
<td>574</td>
<td>50</td>
<td>76.00</td>
<td>12.83</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>CR</td>
<td>18</td>
<td>38</td>
<td>13</td>
<td>22.68</td>
<td>6.00</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>BS</td>
<td>86</td>
<td>1051</td>
<td>36</td>
<td>104.79</td>
<td>87.12</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>OD</td>
<td>6</td>
<td>18</td>
<td>3</td>
<td>8.17</td>
<td>4.08</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CW</td>
<td>10</td>
<td>31</td>
<td>6</td>
<td>11.00</td>
<td>7.38</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

blue baby (BB)  
troubleshooter (TS)  
car repair (CR)  
business-to-business (BS)  
oil drilling problem (OD)  
credit worthiness support system (CW)