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ACTION RULES & META ACTIONS

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Introduction : Action Rule

An action rule /Ras & Wieczorkowska, PKDD 2000/ is a rule extracted from an information system that *describes a possible transition of objects from one state to another* with respect to a distinguished attribute called a decision attribute

Information System

	A	B	D
	a1	b2	d1
	a2	b2	
	a2	b2	d2

Assumption:

- attributes are partitioned into stable and flexible

Values of attributes can be changed

Introduction : Action Rule

Action rule is defined as a term $[(\omega) \wedge (\alpha \rightarrow \beta)] \rightarrow (\phi \rightarrow \psi)$

conjunction of fixed condition features shared by both groups

proposed changes in values of flexible features

desired effect of the action

Information System

	A	B	D
	a1	b2	d1
	a2	b2	
	a2	b2	d2

Example

X	a	b	c	d
x_1	0	S	0	L
x_2	0	R	1	L
x_3	0	S	1	L
x_4	0	R	1	L
x_5	2	P	2	L
x_6	2	P	2	L
x_7	2	S	2	H

Decision Table

{a, c} - stable attributes,

{b, d} - flexible attributes,

d - decision attribute.

Rules discovered:

r_1 = [(b, P) → (d, L)]

r_2 = [(a, 2) ∧ (b, S) → (d, H)]

Action rule:

[(a, 2) ∧ (b, P→ S)](x) ⇒[(d, L→ H)](x)

Application domain: *Customer Attrition*

Facts:

- **On average, most US corporations lose half of their customers every five years (Rombel, 2001).**
- **Longer a customer stays with the organization, the more profitable he or she becomes (Pauline, 2000; Hanseman, 2004).**
- **The cost of attracting new customers is five to ten times more than retaining existing ones.**
- **About 14% to 17% of the accounts are closed for reasons that can be controlled like price or service (Lunt, 1993).**

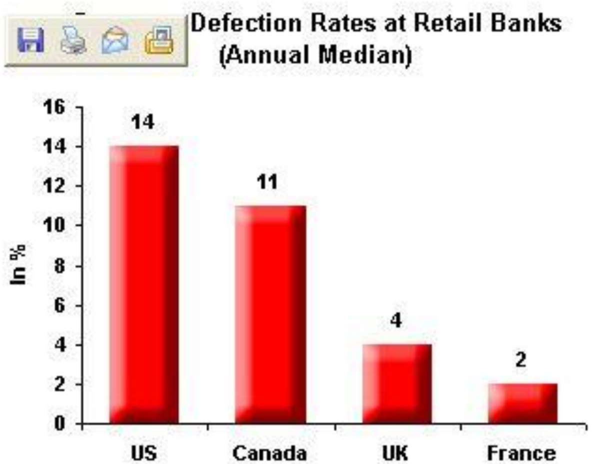
Action:

Reducing the outflow of the customers by 5% can double a typical company's profit (Rombel, 2001).

Customer Attrition in Retail Banking: US, Canada, UK, France

Report Published by Celent

Fighting customer attrition is a top priority at US and Canadian banks, and for good reason: customer defection rates are up to 7 times higher in the US and Canada than in Western Europe. A new Celent report explains why.



In a new report, ***"Customer Attrition in Retail Banking: the US, Canada, the UK, and France,"*** Celent analyzes why customer defection rates are so much higher in the US and Canada than the UK and France.

The report, which is based on a survey of more than 30 banks, reviews trends affecting customer attrition in the UK and France, analyzes how Canadian and American bankers have addressed attrition so far, and reports on their success. The report also suggests tactics that North American banks should pursue to get a 10% defection rate or better.

Over the past two years, half of top US and Canadian banks have seen their defection rates decrease by an average of 10%, while defection rates have remained the same for 40%. Only 10% have experienced increased attrition. The best organizations in the US and Canada have achieved a 12% customer defection rate.

Methods for Action Rules Extraction:

1] Rule-based

Prior extraction of classification rules is needed

Example – DEAR /Tsay & Ras, tree-based strategy/

2] Object-based

Action rules are extracted directly from DB

Example – ARED /similar to Apriori/

Ref 1: "*Action rules discovery: System DEAR2, method and experiments*",
L.-S. Tsay, Z.W. Ras, Journal of Experimental and Theoretical Artificial Intelligence,
Taylor & Francis, Vol. 17, No. 1-2, 2005, 119-128

Ref 2: "*Association Action Rules*", Z.W. Ras, A. Dardzinska, L.-S. Tsay, H. Wasyluk,
IEEE/ICDM Workshop on Mining Complex Data (MCD 2008), Pisa, Italy,
ICDM Workshops Proceedings, IEEE Computer Society, 2008, 283-290

Action Rules Discovery (Preprocessing)

Partition decision table S

a	b	c	e	f	d
2	1	1	7	8	1
2	5	4	6	8	1
1	1	4	9	4	2
1	4	5	8	7	2
2	1	5	2	8	3
2	1	4	2	8	3
1	2	4	7	1	2
2	1	1	6	8	1
3	2	4	6	8	2
3	3	5	7	4	2
3	3	5	6	2	3
2	5	4	6	8	3

Stable:{ a, b}

Flexible: {c, e, f}

Reclassification direction:

2→ 1 or 3 →1

Splitting the node using the stable attribute
Dom(a) = {1,2,3} & Dom(b) = {1,2,3,4,5}

a = 1

T_1

b	c	e	f	d
1	9	4	4	2
4	5	8	7	2
2	4	7	1	2

All objects have the same decision value, so this sub-table is not analyzed any further

a = 2

T_2

b	c	e	f	d
1	1	7	8	1
5	4	6	8	1
1	5	2	8	3
1	4	2	8	3
1	1	6	8	1
5	4	6	8	3

All objects have the same value 8 for attribute f, so it is crossed out from the sub-table (this condition is used for stable attributes as well)

a = 3

T_3

b	c	e	f	d
2	4	6	8	2
3	5	7	4	2
3	5	6	2	3

None of the objects contain the desired class “1”, so this sub-table stops splitting any further

b = 1

T_4

c	e	d
1	7	1
5	2	3
4	2	3
1	6	1

b = 5

T_5

c	e	d
4	6	1
4	6	3

All the flexible values are the same for both objects , therefore this sub-table is not analyzed any further

DEAR - Rule-Based Action Rules Discovery

Set of rules R with supporting objects

Objects	a	b	c	d
x1, x2, x3, x4	0			L
x1, x3			0	L
x2, x4		2		L
x2, x4			1	L
x5, x6		3		L
x7, x8	2	1		H
x7, x8		1	2	H

Stable Attribute: {a, c}

Flexible Attribute: b

Decision Attribute: d

(d, L)-tree T2

Objects	a	b	c
x1, x2, x3, x4	0		
x1, x3			0
x2, x4		2	
x2, x4			1
x5, x6		3	

a = ?

Objects	b	c
x1, x3		0
x2, x4	2	
x2, x4		1
x5, x6	3	

c = ?

Objects	b
x2, x4	2
x5, x6	3

T3

c = 0

Objects	b
x1, x3	

T4

c = 1

Objects	b
x2, x4	

T5

a = 0

Objects	b	c
x1, x2, x3, x4		

c = ?

Objects	b
x1, x2, x3, x4	

T6

(d, H)-tree T1

Objects	a	b	c
x7, x8	2	1	
x7, x8		1	2

a = 2

Objects	b	c
x7, x8	1	

c = ?

Objects	b
x7, x8	1

T1

a = ?

Objects	b	c
x7, x8	1	2

c = 2

Objects	b
x7, x8	1

T2

(T3, T1) : $(a = 2) \wedge (b, 2 \rightarrow 1) \Rightarrow (d, L \rightarrow H)$

$(a = 2) \wedge (b, 3 \rightarrow 1) \Rightarrow (d, L \rightarrow H)$

ARED – Object Based Action Rule Discovery

$(a, a_1 \rightarrow a_1)$ (a, a_1) $Y = \{x_2, x_4\}$

$(a, a_2 \rightarrow a_2)$ (a, a_2) $Z = \{x_1, x_2, x_3, x_4, x_5, x_7\}$

$(b, b_1 \rightarrow b_1)$

$(b, b_2 \rightarrow b_2)$

………..

$(d, d_1 \rightarrow d_1)$

$(d, d_2 \rightarrow d_2)$

atomic action terms

Decision System *S*

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

$r = [(a, a_2 \rightarrow a_2)*(b, b_1 \rightarrow b_1)] \rightarrow (d, d_1 \rightarrow d_1)$

action rule

$(w, w) \in (Y, Y) \rightarrow (w, w) \in (Z, Z)$

Support: $$\sup(r) = card(Y \cap Z)$$

Confidence: $$conf(r) = \left[\frac{card(Y \cap Z)}{card(Y)}\right]$$

sup(r) = 2

conf(r) = 2/2 = 1

Decision System S

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

$(a, a_1 \rightarrow a_1)$
$(a, a_1 \rightarrow a_2)$
$(b, b_1 \rightarrow b_2)$
$(b, b_2 \rightarrow b_2)$
....
$(d, d_1 \rightarrow d_1)$
$(d, d_2 \rightarrow d_2)$

atomic action terms

$r=[(a, a_2 \rightarrow a_1)*(b, b_1 \rightarrow b_1)] \rightarrow (d, d_1 \rightarrow d_2)$

(Y_1, Y_2) (Z_1, Z_2)

rule

sup(r) = 2
conf(r) = 1/2

$Y_1 = \{x_2, x_4\}$
$Z_1 = \{x_1, x_2, x_3, x_4, x_5, x_7\}$
$Y_2 = \{x_1, x_6\}$
$Z_2 = \{x_6\}$

$$\sup(r) = card(Y_1 \cap Z_1)$$

$$conf(r) = \left[\frac{card(Y_1 \cap Z_1)}{card(Y_1)}\right] * \left[\frac{card(Y_2 \cap Z_2)}{card(Y_2)}\right]$$

Decision System S

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

$Y_1 = \{x_2, x_4\}$
$Z_1 = \{x_1, x_2, x_3, x_4, x_5, x_7\}$
$Y_2 = \{x_1, x_6\}$
$Z_2 = \{x_6\}$

$(a, a_1 \to a_1)$
$(a, a_1 \to a_2)$
$(b, b_1 \to b_2)$
$(b, b_2 \to b_2)$
....
$(d, d_1 \to d_1)$
$(d, d_2 \to d_2)$

atomic terms

$r = [(a, a_2 \to a_1) * (b, b_1 \to b_1)] \to (d, d_1 \to d_2)$

(Y_1, Y_2) (Z_1, Z_2)

rule

sup(r) = 1
conf(r) = 1/2

$$\sup(r) = \min\{ card(Y_1 \cap Z_1), card(Y_2 \cap Z_2)\}$$

$$conf(r) = \left[\frac{card(Y_1 \cap Z_1)}{card(Y_1)}\right] * \left[\frac{card(Y_2 \cap Z_2)}{card(Y_2)}\right]$$

ARED

λ1 - minimum support, λ2 - minimum confidence

Object reclassification from class d_1 to d_2 λ1=2, λ2=1/4

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

flexible attributes

stable attribute

Meaning of $(d, d_1 \rightarrow d_2)$ in S:

$$N_S(d, d_1 \rightarrow d_2) = [\{x_1, x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$$

Atomic classification terms:

$(b, b_1 \rightarrow b_1)$, $(b, b_2 \rightarrow b_2)$, $(b, b_3 \rightarrow b_3)$
$(a, a_1 \rightarrow a_2)$, $(a, a_1 \rightarrow a_1)$, $(a, a_2 \rightarrow a_2)$, $(a, a_2 \rightarrow a_1)$
$(c, c_1 \rightarrow c_2)$, $(c, c_2 \rightarrow c_1)$, $(c, c_1 \rightarrow c_1)$, $(c, c_2 \rightarrow c_2)$

ARED

$\lambda 1$ - **minimum support**, $\lambda 2$ - **minimum confidence**

Object reclassification from class d_1 to d_2 $\lambda 1=2$, $\lambda 2=1/4$

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

stable attribute

flexible attributes

Notation:

$t_1=(b,b_1\rightarrow b_1)$, $t_2=(b,b_2\rightarrow b_2)$, $t_3=(b,b_3\rightarrow b_3)$,

$t_4=(a,a_1\rightarrow a_2)$, $t_5=(a,a_1\rightarrow a_1)$, $t_6=(a,a_2\rightarrow a_2)$, $t_7=(a,a_2\rightarrow a_1)$,

$t_8=(c,c_1\rightarrow c_2)$, $t_9=(c,c_2\rightarrow c_1)$, $t_{10}=(c,c_1\rightarrow c_1)$, $t_{11}=(c,c_2\rightarrow c_2)$,

$t_{12} = (d,d_1 \rightarrow d_2)$.

Object reclassification from class d_1 to d_2 $\lambda1=2, \lambda2=1/4$

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

$$\sup(r) = card(Y_1 \cap Z_1)$$

For decision attribute in S:

$N_S(d,d_1 \rightarrow d_2)=[\{x_1,x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$

For classification attribute in S:

Not marked $\lambda1=3$	$N_S(t_1) = N_S(b,b_1 \rightarrow b_1) = [\{x_1,x_2, x_4, x_6\}, \{x_1,x_2, x_4, x_6\}]$
Mark "-" $\lambda2=0$	$N_S(t_2) = N_S(b,b_2 \rightarrow b_2) = [\{x_3,x_7, x_8\}, \{x_3,x_7, x_8\}]$
Mark "-" $\lambda1=1$	$N_S(t_3) = N_S(b,b_3 \rightarrow b_3) = [\{x_5\}, \{x_5\}]$
Mark "-" $\lambda2=0$	$N_S(t_4) = N_S(a,a_1 \rightarrow a_2) = [\{x_1,x_6, x_7, x_8\}, \{x_2,x_3, x_4, x_5\}]$

Object reclassification from class d_1 to d_2 $\lambda 1=2,\ \lambda 2=1/4$

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

For decision attribute in S:

$N_S(d,d_1 \rightarrow d_2)=[\{x_1,x_2,\ x_3,\ x_4,\ x_5,\ x_7\},\ \{x_6\}]$

For classification attribute in S:

Not marked $\lambda 1=2$
Mark "-" $\lambda 2= 0$
Mark "+" $\lambda 1=4, \lambda 2=1/4$

$N_S(t_5) = N_S(a,a_1 \rightarrow a_1) = [\{x_1,x_6,\ x_7,\ x_8\},\ \{x_1,x_6,\ x_7,\ x_8\}]$

$N_S(t_6)= N_S(a,a_2 \rightarrow a_2) = [\{x_2,x_3,\ x_4,\ x_5\},\ \{x_2,x_3,\ x_4,\ x_5\}]$

$N_S(t_7)= N_S(a,a_2 \rightarrow a_1) = [\{x_2,x_3,\ x_4,\ x_5\},\ \{x_1,x_6,\ x_7,\ x_8\}]$

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

Object reclassification from class d1 to d2

λ1=2, λ2=1/4

For decision attribute in S:

$N_S(t_{12})=[\{x_1,x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$

For classification attribute in S:

Not marked λ1=3	$N_S(t_1)=[\{x_1,x_2, x_4, x_6\}, \{x_1,x_2, x_4, x_6\}]$
Marked "-" λ2=0	$N_S(t_2)=[\{x_3,x_7, x_8\}, \{x_3,x_7, x_8\}]$
Marked "-" λ1=1	$N_S(t_3)=[\{x_5\}, \{x_5\}]$
Marked "-" λ2=0	$N_S(t_4)=[\{x_1,x_6, x_7, x_8\}, \{x_2,x_3, x_4, x_5\}]$
Not marked λ1=2	$N_S(t_5)=[\{x_1,x_6, x_7, x_8\}, \{x_1,x_6, x_7, x_8\}]$
Marked "-" λ2=0	$N_S(t_6)=[\{x_2,x_3, x_4, x_5\}, \{x_2,x_3, x_4, x_5\}]$
Mark "+" λ1=4, λ2=1/4	$N_S(t_7)=[\{x_2,x_3, x_4, x_5\}, \{x_1,x_6, x_7, x_8\}]$

$r = [t_7 \rightarrow t_1]$

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

Object reclassification from class d1 to d2

λ1=2, λ2=1/4

For decision attribute in S:

$$N_S(t_{12})=[\{x_1,x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$$

For classification attribute in S:

conf = 2/3 *1/5 <λ_2

Not marked	$N_S(t_8)= N_S(c,c_1\rightarrow c_2) = [\{x_1,x_4, x_8\}, \{x_2, x_3, x_5, x_6, x_7\}]$
Marked "-"	$N_S(t_9) = N_S(c,c_2\rightarrow c_1) = [\{x_2, x_3, x_5, x_6, x_7\}, \{x_1, x_4, x_8\}]$
Marked "-"	$N_S(t_{10}) = N_S(c,c_1\rightarrow c_1) = [\{x_1, x_4, x_8\}, \{x_1, x_4, x_8\}]$
Not marked	$N_S(t_{11}) = N_S (c,c_2\rightarrow c_2)= [\{x_2, x_3, x_5, x_6, x_7\}, \{x_2, x_3, x_5, x_6, x_7\}]$

Object reclassification from class d1 to d2 λ1=2, λ2=1/4

Now action terms of length 2 from unmarked action terms of length 1

For decision attribute in S:

$N_S(t_{12})=[\{x_1,x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$

For classification attribute in S:

$N_S(t_1)=[\{x_1,x_2, x_4, x_6\}, \{x_1,x_2, x_4, x_6\}]$, $N_S(t_5)=[\{x_1,x_6, x_7, x_8\}, \{x_1,x_6, x_7, x_8\}]$,

$N_S(t_8)=[\{x_1,x_4, x_8\}, \{x_2, x_3, x_5, x_6, x_7\}]$, $N_S(t_{11})= [\{x_2, x_3, x_5, x_6, x_7\}, \{x_2, x_3, x_5, x_6, x_7\}]$.

Marked "-", λ1=1	$N_S(t_1{*}t_5)=[\{x_1, x_6\}, \{x_1, x_6\}]$
Marked "+"	$N_S(t_1{*}t_8)=[\{x_1, x_4\}, \{x_2, x_6\}]$

Rule r = [$t_1{*}t_8 \rightarrow t_{12}$], conf = 1/2 ≥ λ_2, sup=2 ≥ λ_1

Marked "-", λ1=1	$N_S(t_1{*}t_{11})=[\{x_2, x_6\}, \{x_2, x_6\}]$
Marked "-", λ1=1	$N_S(t_5{*}t_8)=[\{x_1, x_8\}, \{x_6, x_7\}]$
Marked "-", λ1=1	$N_S(t_5{*}t_{11})=[\{x_6, x_7\}, \{x_6, x_7\}]$
Marked "-"	$N_S(t_8{*}t_{11})=[\varnothing, \{x_2, x_3, x_5, x_6, x_7\}]$

ARED

Object reclassification from class d1 to d2 λ1=2, λ2=1/4

For decision attribute in S:

$N_S(t_{12})=[\{x_1,x_2, x_3, x_4, x_5, x_7\}, \{x_6\}]$

For classification attribute in S:

Action rules:

[[(b,b1→b1)(c,c1→c2)] → (d, d1→d2)]*

[[(a,a2→a1] → (d, d1→d2)]

X	a	b	c	d
x_1	a_1	b_1	c_1	d_1
x_2	a_2	b_1	c_2	d_1
x_3	a_2	b_2	c_2	d_1
x_4	a_2	b_1	c_1	d_1
x_5	a_2	b_3	c_2	d_1
x_6	a_1	b_1	c_2	d_2
x_7	a_1	b_2	c_2	d_1
x_8	a_1	b_2	c_1	d_3

Association Action Rules

Atomic Action Terms:

1. $(a, a_1 \rightarrow a_2)$, *where* a *is symbolic attribute*

attribute

$a_1, a_2 \in V_a$

if $a_1 = a_2$ then a – stable on a_1

2. $(a, [a_1, a_2]\uparrow[a_3, a_4])$, *where* a *is numerical*, $a_1 \leq a_2 < a_3 \leq a_4$, *and* $a_i \in V_a$

3. $(a, [a_1, a_2]\downarrow[a_3, a_4])$, *where* a *is numerical*, $a_1 \leq a_2 < a_3 \leq a_4$, *and* $a_i \in V_a$

$\uparrow$ - value is increased ; $\downarrow$ - value is decreased

Association Action Rules

Candidate action set - any collection of atomic actions

Action set - candidate action set which does not contain two atomic actions referring to the same attribute

Example: $\{(b, b_2), (b, [b_1, b_2] \uparrow [b_3, b_4])\}$ – candidate action set but not action set.

Action term - conjunction of atomic actions forming an action set.

Example: $(a, a_2) \wedge (c, c_1 \rightarrow c_2) \wedge (b, [b_1, b_2] \uparrow [b_3, b_4])$

Association Action Rules

Interpretation N_S of action terms in S=(X,A,V):

$N_S((a, a_1 \rightarrow a_2)) = [\{x \in X : a(x) = a_1\}, \{x \in X : a(x) = a_2\}]$.

$N_S((a, [a_1, a_2] \downarrow [a_3, a_4])) =$
$[\{x \in X : a_1 \leq a(x) \leq a_2\}, \{x \in X : a_3 \leq a(x) \leq a_4\}]$

$N_S((a, [a_1, a_2] \uparrow [a_3, a_4])) =$
$[\{x \in X : a_1 \leq a(x) \leq a_2\}, \{x \in X : a_3 \leq a(x) \leq a_4\}]$

$N_S((a, \uparrow [a_3, a_4])) =$
$[\{x \in X : a(x) < a_3\}, \{x \in X : a_3 \leq a(x) \leq a_4\}]$

$N_S((a, [a_3, a_4] \uparrow)) =$
$[\{x \in X : a_3 \leq a(x) \leq a_4\}, \{x \in X : a_4 < a(x)\}]$

Association Action Rules

Information System *S=(X, A, V)*

Action Rule: $r = [t \rightarrow t']$ $t = t_1 \wedge t_2 \wedge \ldots \wedge t_k$

$N_S(t)=[Y_1, Y_2]$ $N_S(t')=[Z_1, Z_2]$

Atomic actions

Support: $\sup(r) = \min\{card(Y_1 \cap Z_1), card(Y_2 \cap Z_2)\}$

Confidence: $conf(r) = \left[\frac{card(Y_1 \cap Z_1)}{card(Y_1)}\right] \cdot \left[\frac{card(Y_2 \cap Z_2)}{card(Y_2)}\right]$

Meta-actions /A. Tuzhilin (2006)/
Actions which trigger changes of flexible attributes either directly or indirectly because of correlations among certain attributes in the system.

Example 1: Taking a drug /Lamivudine is used for treatment of chronic hepatitis B. It *improves the seroconversion of e-antigen positive hepatitis B* and also *improves histology staging of the liver* but at the same time it can cause a number of other symptoms. This is why doctors have to order certain lab tests to check patient's response to that drug.

Example 2: Classification attributes are: *Explain difficult concepts effectively, Stimulate student interest in the course, Provide sufficient feedback.*
Meta-actions : *Change the content of the course, Change the textbook of the course, …*

Action Rules - continuation

Influence Matrix

$A_1, A_2, A_3, \ldots, A_m$ – attributes
$M_1, M_2, M_3, \ldots, M_n$ – meta actions
E_{ij} – atomic action or NULL, $i \leq m, j \leq n$

	A_1	A_2	A_3	A_4	…..	A_m
M_1	E_{11}	E_{12}	E_{13}	E_{14}		E_{1m}
M_2	E_{21}	E_{22}	E_{23}	E_{24}		E_{2m}
M_3	E_{31}	E_{32}	E_{33}	E_{34}		E_{3m}
M_4	E_{41}	E_{42}	E_{43}	E_{44}		E_{4m}
…..						
M_n	E_{m1}	E_{m2}	E_{m3}	E_{m4}		E_{mn}

Atomic actions triggered by M_3

Action rule: $r = [t \Rightarrow (d, d_1 \rightarrow d_2)]$, where t – action term

Action Rules - continuation

Meta-actions based decision system $S(d)=(X, A \cup \{d\}, V)$,
with $A = \{A_1, A_2, \ldots, A_m\}$

	A_1	A_2	A_3	A_4	…..	A_m
M_1	E_{11}	E_{12}	E_{13}	Null		E_{1m}
M_2	Null	E_{22}	E_{23}	E_{24}		E_{2m}
M_3	E_{31}	E_{32}	Null	Null		Null
M_4	E_{41}	Null	E_{43}	E_{44}		E_{4m}
…..						
M_n	E_{m1}	Null	E_{m3}	E_{m4}		E_{mn}

Influence Matrix

Meta-action M_3 triggers two atomic actions:

$\{E_{32} = [a_2 \rightarrow a_2'],$
$E_{31} = [a_1 \rightarrow a_1']\}$

Candidate action rule -
$\mathbf{r} = [(A_1, a_1 \rightarrow a_1') \wedge (A_2, a_2 \rightarrow a_2') \wedge (A_4, a_4 \rightarrow a_4')]) \Rightarrow (d, d_1 \rightarrow d_1')$

We say that r is valid in S with respect to meta-action M_3 if the atomic actions triggered by M_3 do not contradict with atomic actions in r.

Action Rules - continuation

Meta-actions based decision system $S(d)=(X, A \cup \{d\}, V)$,
with $A = \{A_1, A_2, \ldots, A_m\}$

Influence Matrix

	A_1	A_2	A_3	A_4	…..	A_m
M_1	E_{11}	E_{12}	E_{13}	E_{14}		E_{1m}
M_2	E_{21}	E_{22}	E_{23}	E_{24}		E_{2m}
M_3	E_{31}	E_{32}	E_{33}	E_{34}		E_{3m}
M_4	E_{41}	E_{42}	E_{43}	E_{44}		E_{4m}
…..						
M_n	E_{m1}	E_{m2}	E_{m3}	E_{m4}		E_{mn}

We say that action rule r extracted from S(d) is supported by meta-actions in $M=\{M_{i1}, M_{i2}, \ldots, M_{in}\}$, if r is valid in S with respect to each meta-action in M and each atomic action at the left-hand side of r is triggered by minimum one meta-action in M.

Action Rules Discovery - Example

	a	**b**	**c**
M_1		b_1	$c_2 \to c_1$
M_2	$a_2 \to a_1$	b_2	
M_3	$a_1 \to a_2$		$c_2 \to c_1$
M_4		b_1	$c_1 \to c_2$
M_5			$c_1 \to c_2$
M_6	$a_1 \to a_2$		$c_1 \to c_2$

Influence Matrix for S(d)

Candidate action rules:

$r_1 = [[(b, b_1) \wedge (c, c_1 \to c_2)]) \Rightarrow (d, d_1 \to d_2)]$, valid with respect to M_4, M_5, M_6

$r_2 = [(a, a_2 \to a_1)) \Rightarrow (d, d_1 \to d_2)]$, valid with respect to M_2, M_4, M_5 but not valid with respect to M_2

Application Domain

Database HEPAR (Medical Center of Postgraduate Education, Warsaw, Poland) prepared by Dr. med. Hanna Wasyluk

- 758 patients described by 106 attributes (including 31 laboratory tests with values discretized to: "below normal", "normal", "above normal"). 14 attributes are stable. Two tests are invasive tests: HBsAg [in tissue], HBcAg [in tissue]. There are 7 decision values (attribute d):

I. Acute hepatitis
IIa. Subacute hepatitis (types BC)
IIb. Subacute hepatitis (alcohol-abuse)
IIIa. Chronic hepatitis (curable)
IIIb. Chronic hepatitis (non-curable)
IV. Cirrhosis hepatitis
V. Liver cancer

We ask for re-classifications: IIb $\rightarrow$ I, IIIa $\rightarrow$ I

Application Domain

Chosen d-reduct has no invasive tests, 11% incomplete data

{m, n, q, u, y, aa, ah, ai, am, an, aw, bb, bg, by, cj, cm}

m	Bleeding
n	Subjaundice symptoms
q	Eructation
u	Obstruction
y	Weight loss
aa	Smoking
ah	History of viral hepatitis (stable)
ai	Surgeries in the past (stable)
am	History of hospitalization (stable)
an	Jaundice in pregnancy
aw	Erythematous dermatitis
bb	Cysts
bg	Sharp liver edge (stable)
bm	Blood cell plaque
by	Alkaline phosphatase
cj	Prothrombin index
cm	Total cholesterol
d	**Decision attribute**

Application Domain: Database HEPAR

- No history of viral hepatitis but with history of surgery and hospitalization, sharp
- liver edge normal, no subjaundice symptoms, total cholesterol normal,
- erythematous dermatitis normal, weight normal, no cysts , patient does not smoke

- $[(ah=1) \wedge (ai=2) \wedge (am=2) \wedge (bg=1)] \wedge (cm=1) \wedge (aw=1) \wedge (u, \rightarrow 1) \wedge (bb=1) \wedge (aa=1)$
- $\wedge (q, \rightarrow 1) \wedge (m, \rightarrow 1) \wedge (n=1) \wedge (bm, \rightarrow up) \wedge (y=1) \wedge (by, \rightarrow up)$
- $\rightarrow (d, IIIa \rightarrow I)$

- $[(ah=1) \wedge (ai=2) \wedge (am=2) \wedge (bg=1)] \wedge (cm=1) \wedge (aw=1) \wedge (u, \rightarrow 1) \wedge (bb=1) \wedge (aa=1)$
- $\wedge (q, \rightarrow 1) \wedge (m, \rightarrow 1) \wedge (n=1) \wedge (bm, \rightarrow up) \wedge (y=1) \wedge (by, \rightarrow down)$
  $\rightarrow (d, IIIa \rightarrow I)$
- Two quite similar action rules have been constructed:
  By getting rid of obstruction, eructation, bleeding, by decreasing the blood cell plaque and by changing the level of alkaline phosphatase we should be able reclassify the patient from IIIa group to I.

Attribute values of *total cholesterol, weight, and smoking* have to stay unchanged.

Cost of Meta Action Rules

	Meta Actions (drugs)	
Action Rule II requires getting rid of:		
- *obstruction (u)*	HEPATIL	TRIPHALA
- *eructation (q)*	HEPATIL	HEPARGEN
- *bleeding (m)*	HEPATIL	HEPARGEN
decreased blood cell plaque (bm)	HEPATIL	HEPARGEN
increased level of alkaline phosphatase (by)	HEPATIL	HEPARGEN

[(ah=1)∧ (ai=2)∧ (am=2)∧ (bg=1)]*∧(cm=1)∧(aw=1)∧(u, → 1)∧ (bb=1)∧ (aa=1) ∧ (q, → 1)∧(m, → 1)∧(n=1)∧(bm, → up)∧(y=1)∧* ***(by, → down)***
→ (d, IIIa → I)

==

[(ah=1)∧ (ai=2)∧ (am=2)∧ (bg=1)]*∧(cm=1)∧(aw=1)∧ (bb=1)∧ (aa=1) ∧(n=1)∧(y=1) ∧ [obstruction, eructation, bleeding, increased blood cell plaque, increased level of alkaline phosphatase] ∧ [Take HEPATIL] →* ***(d, IIIa → I)***

[(ah=1)∧ (ai=2)∧ (am=2)∧ (bg=1)]*∧(cm=1)∧(aw=1)∧ (bb=1)∧ (aa=1) ∧ (n=1) ∧ (y=1) ∧ [obstruction, eructation, bleeding, increased blood cell plaque, increased level of alkaline phosphatase] ∧ [Take HEPERGEN & TRIPHALA] →* ***(d, IIIa → I)***

Simple Association Action Rules

$(a, a_1 \rightarrow a_2)$ - atomic action set

$cost((a, a_1 \rightarrow a_2))$ - cost of action expecting to change value of attribute a from a_1 to a_2.

$t_1 = (a, a_1 \rightarrow a_2)$, $t_2 = (b, b_1 \rightarrow b_2)$ - two atomic action sets

t_1, t_2 are positively correlated if *changes* t_1, t_2 support each other

Change t_1 implies change t_2 and t_2 implies change t_1.

Simple Association Action Rules

Definition:

Let $t = t_1 * t_2 * \ldots * t_m$ is a frequent action set, where each t_i - atomic action set.

Let $T = \{t_1, t_2, \ldots, t_m\}$ and:

$t_i \sim t_j$ iff t_i and t_j are positively correlated.

Equivalence relation, partitions T into equivalence classes ($T = T_1 \cup T_2 \cup \ldots \cup T_k$)

Simple Association Action Rules

Definition:

Let $t = t_1 * t_2 * \ldots * t_m$ is a frequent action set, where each t_i - atomic action set.

Let $T = \{t_1, t_2, \ldots, t_m\}$ and:

$t_i \sim t_j$ iff t_i and t_j are positively correlated.

Now:

In each equivalence class T_i, an atomic action set $a(T_i)$ of the lowest cost is identified.

The cost of t is defined as: $cost(t) = \sum\{\mathrm{cost}(a(T_i)): 1 \leq i \leq k\}$

Simple Association Action Rules

Definition:

Let $t = t_1 * t_2 * \ldots * t_m$ is a frequent action set, where each t_i - atomic action set.

Let $T = \{t_1, t_2, \ldots, t_m\}$ and:

$t_i \sim t_j$ iff t_i and t_j are positively correlated.

Now:

The cost of t is defined as: $cost(t) = \sum\{cost(a(T_i)) : 1 \leq i \leq k\}$

$a(T_1) * a(T_2) * \ldots * a(T_k) \rightarrow [t - \{a(T_i): 1 \leq i \leq k\}]$

- simple association action rule.

Simple Association Action Rules

Definition:

Let $t = t_1 * t_2 * \ldots * t_m$ is a frequent action set, where each t_i - atomic action set.

Let $T = \{t_1, t_2, \ldots, t_m\}$ and:

$t_i \sim t_j$ iff t_i and t_j are positively correlated.

Now:

The cost of t is defined as: $cost(t) = \sum\{cost(a(T_i)): 1 \leq i \leq k\}$

$r = [\, a(T_1) * a(T_2) * \ldots * a(T_k) \rightarrow [t - \{a(T_i): 1 \leq i \leq k\}]\,]$ - simple association action rule.

The cost of r is defined as the cost of $a(T_1) * a(T_2) * \ldots * a(T_k)$

Some Publications

"Application of Action Rules to HEPAR Clinical Decision Support System", H. Wasyluk, Z.W. Ras, E. Wyrzykowska, in *Experimental and Clinical Hepatology Journal*, Vol. 4, No. 2, 2008

"Action Rules Discovery based on Tree Classifiers and Meta-Actions", Z. Ras, A. Dardzinska, in *Foundations of Intelligent Systems*, Proceedings of ISMIS'09, (Eds. J. Rauch et al), LNAI, Vol. 5722, Springer, 2009, 66-75

“Action Rule Discovery From Incomplete Data", S. Im, Z.W. Ras, H. Wasyluk, in *Knowledge and Information Systems Journal*, Springer, 2009

"Association Action Rules", Z.W. Ras, A. Dardzinska, L.-S. Tsay, H. Wasyluk, *IEEE/ICDM Workshop on Mining Complex Data* (MCD 2008), Pisa, Italy, ICDM Workshops Proceedings, IEEE Computer Society, 2008, 283-290

"Action Rules Discovery without pre-existing classification rules“, Z.W. Ras, A. Dardzinska, in *Proceedings of RSCTC 2008 Conference*, Akron, Ohio, LNAI 5306, Springer, 2008, 181-190

Questions?

Thank You