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European University Alliance

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Decision Support Systems, Machine Learning Models, Learning Decision Support System Models from Data

Prof. Dr. Boris Delibašić, University of Belgrade



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Circle U.

University of Belgrade – Faculty of Organizational Sciences

Engineering Optimization Information Systems Management

Expertise of Prof. Boris Delibašić's group

1. Machine learning algorithm design
2. Development of decision support systems with multicriteria decision-making methods
3. Voting and computational social choice
4. Real decision support and machine learning models applications.



Computational Social Choice

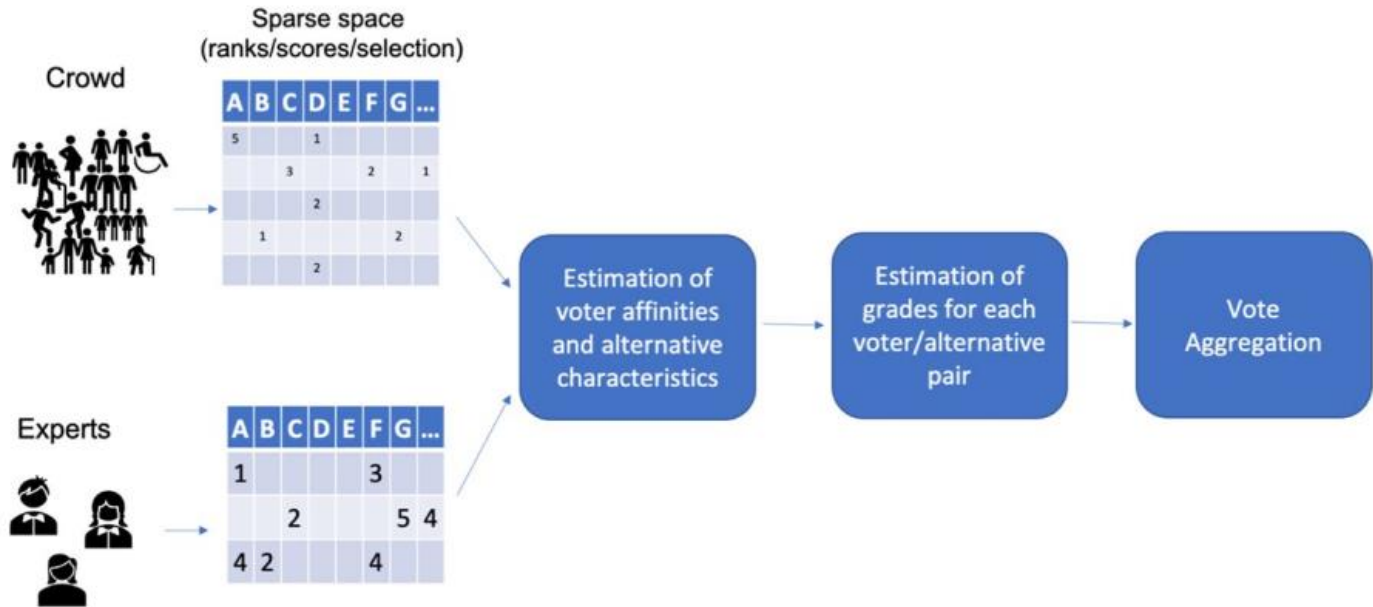


Fig. 1 General data flow of BargCrEx



BargCrEx: A System for Bargaining Based Aggregation of Crowd and Expert Opinions in Crowdsourcing

Ana Vukicevic^{1,2} · Milan Vukicevic¹ · Sandro Radovanovic¹ · Boris Delibasic¹

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Data Science

- Data Mining – Data Science – AI
- Data is the fuel upon which **models** for decision-making are built.
- These models can automate the decision-making process and **replace decision-makers**.
- The **utility function (risk aversion)** is learned from data.
- The requirements of the models are:
 - Correctness
 - Automatisisation (Convenient property)
 - Responsibility (in recent years)

Decision Support Systems

- Designed to satisfy the 5C requirements (Bohanec, 2021):
 - Correctness (☒ ☐) => Misalignment
 - Completeness (☐) => Out-of-the-sample
 - Consistency (☐) => Responsible AI
 - Comprehensibility (☐) => XAI
 - Convenience (☒ ☐) => Sensitivity analysis, Counterfactual
- Models are handcrafted based on expert knowledge.
- The **utility function** is defined by the expert.
- It is easy to do what-if analysis.

The Decision Tree Machine Learned Model

Selected Attributes:

1. Day Minutes
2. Customer Service Calls
3. Voice Mail Messages
4. Eve Minutes
5. International Plan: Yes/No
6. International Calls
7. International Minutes

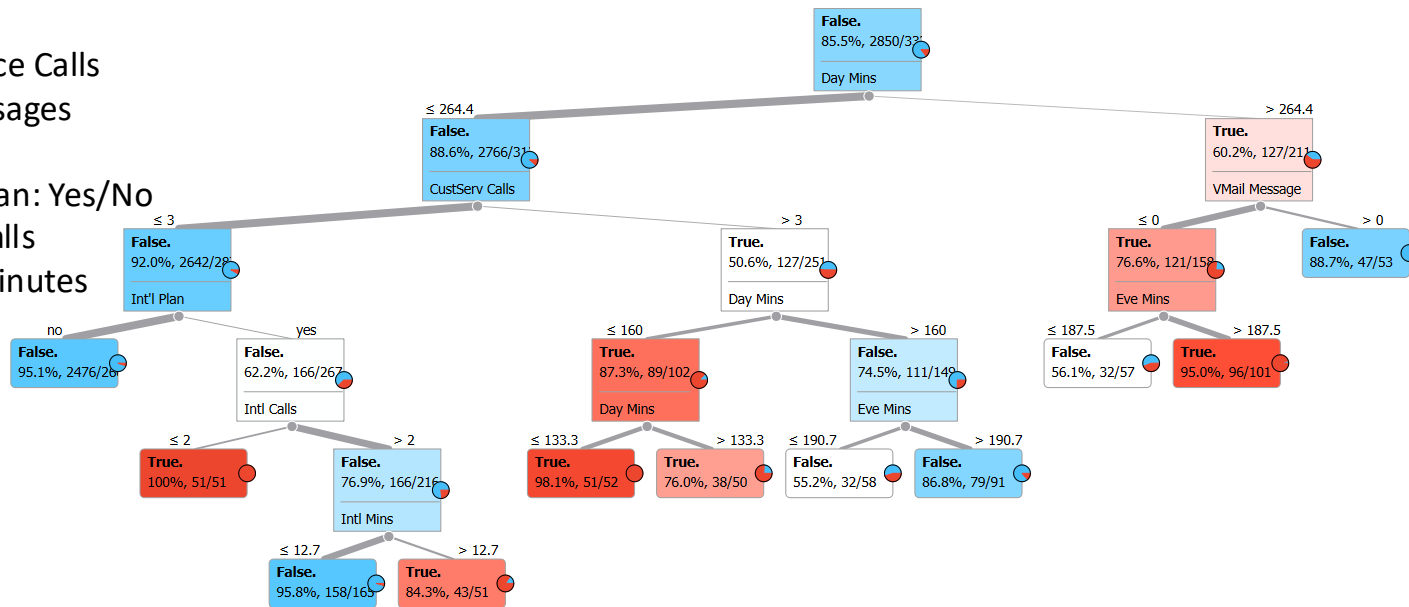
Performance:

Accuracy: 90.7%

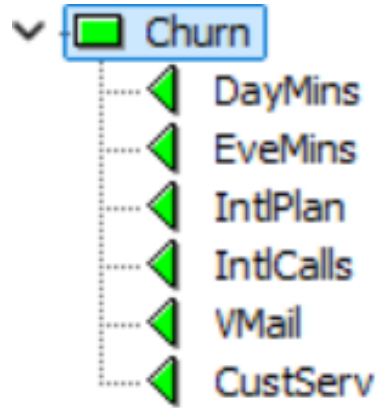
Recall: 56.7%

Precision: 73.3%

F1: 63.9%



The DEX model– Expert made



DayMins	EveMins	IntlPlan	IntlCalls	VMail	CustServ	Churn
1	2	yes	1	no	1	yes
1	2	yes	1	no	2	yes
1	2	yes	1	yes	1	yes
1	2	yes	1	yes	2	yes
1	2	yes	2	no	1	no
1	2	yes	2	no	2	yes
1	2	yes	2	yes	1	no
1	2	yes	2	yes	2	yes
1	2	no	1	no	1	no
1	2	no	1	no	2	yes
1	2	no	1	yes	1	no
1	2	no	1	yes	2	yes
1	2	no	2	no	1	no
1	2	no	2	no	2	yes
1	2	no	2	yes	1	no
1	2	no	2	yes	2	yes
1	1	yes	1	no	1	yes
1	1	yes	1	no	2	yes
1	1	yes	1	yes	1	yes
1	1	yes	1	yes	2	yes
1	1	yes	2	no	1	no
1	1	yes	2	no	2	yes
1	1	yes	2	yes	1	no
1	1	yes	2	yes	2	yes
1	1	no	1	no	1	no
1	1	no	1	no	2	yes
1	1	no	1	yes	1	no
1	1	no	1	yes	2	yes
1	1	no	2	no	1	no
1	1	no	2	no	2	yes
1	1	no	2	yes	1	no
1	1	no	2	yes	2	yes

DEX model + Data

	DayMins	EveMins	IntlPlan	IntlCalls	VMail	CustServ	Churn
1	1	2	yes	1	no	1	yes
2	1	2	yes	1	no	2	yes
3	1	2	yes	1	yes	1	yes
4	1	2	yes	1	yes	2	yes
5	1	2	yes	2	no	1	no
6	1	2	yes	2	no	2	yes
7	1	2	yes	2	yes	1	no
8	1	2	yes	2	yes	2	yes
9	1	2	no	1	no	1	no
10	1	2	no	1	no	2	yes
11	1	2	no	1	yes	1	no
12	1	2	no	1	yes	2	yes
13	1	2	no	2	no	1	no
14	1	2	no	2	no	2	yes
15	1	2	no	2	yes	1	no
16	1	2	no	2	yes	2	yes
17	1	1	yes	1	no	1	yes
18	1	1	yes	1	no	2	yes
19	1	1	yes	1	yes	1	yes
20	1	1	yes	1	yes	2	yes
21	1	1	yes	2	no	1	no
22	1	1	yes	2	no	2	yes
23	1	1	yes	2	yes	1	no
24	1	1	yes	2	yes	2	yes
25	1	1	no	1	no	1	no
26	1	1	no	1	no	2	yes
27	1	1	no	1	yes	1	no
28	1	1	no	1	yes	2	yes
29	1	1	no	2	no	1	no
30	1	1	no	2	no	2	yes
31	1	1	no	2	yes	1	no
32	1	1	no	2	yes	2	yes

+

	DayMins	EveMins	Calls	CustServ Calls	Intl Calls	Churn?
1	3	1	0	1	1	No
2	2	1	0	1	1	No
3	3	1	1	1	2	No
4	3	1	1	2	2	No
5	2	1	1	2	1	No
6	3	2	1	1	2	No
7	3	2	1	2	2	No
8	2	1	1	1	2	No
9	2	2	0	1	1	No
10	3	2	1	1	2	No
...	...	...	...	...	...	...
3333	3	2	0	1	1	No

=

	Churn (DSS)
1	No
2	No
3	No
4	No
5	No
6	Yes
7	No
8	No
9	No
10	No
...	...
3333	No

96 rules in one table

±1 Analysis (What-If Analysis)

Attribute	-1	6	+1
Churn		yes	
DayMins	no	3	]
EveMins	[	2	no
IntlPlan	[	yes	
IntlCalls		2	]
VMail	[	no	no
CustServ	[	1	

Attribute	-1	3328	+1
Churn		yes	
DayMins	[	1	no
EveMins		1	]
IntlPlan		no	]
IntlCalls		2	]
VMail	[	no	
CustServ	no	2	]

Sources:

Delibašić B., Radovanović S., Bohanec M., Suknović M. (2025) A comparison between DSS and ML models for churn prediction, ICDSST 2025, Belgrade, Serbia.

The main questions

- How to combine the worlds of Data Science and Decision Support Systems model, i.e. data and expert modeling?
- Is this convenient?
- Why this is not done more frequently?
- Data Science models should be updated to DSS.
- Yes, but it takes some multidisciplinary understanding.
- This is not mainstream.

Developing DEX Models from Data

Algorithm 1. DIDEX algorithm

```
Data:  $X$  - attributes,  $y$  - label, and  $w$  weights  
Result:  $dex$  - DEX model  
1 BestBIC = Inf, BestDEXModel = None;  
2 ;  
3 dex.appendFinalDecisionTable(createDecisionTable( $X$ ,  $y$ ));  
4 BestBIC = calculateBic(dex); BestDEXModel = dex;  
5 while  $continue = True$  do  
6   bestInteraction = findBestInteraction( $X$ ,  $y$ ,  $w$ );  
7    $X.add(bestInteraction)$ ;  
8   ;  
9   dex.appendToHierarchy(bestInteraction);  
10  dex.appendDecisionTable(createDecisionTable(bestInteraction,  $y$ ));  
11  dex.removeFinalDecisionTable();  
12  dex.appendFinalDecisionTable(createDecisionTable( $X$ ,  $y$ ));  
13  ;  
14  BIC = calculateBic(dex);  
15  if  $BIC \leq BestBIC$  then  
16    BestBIC = BIC; BestDEXModel = dex;  
17  else  
18     $continue = False$ ;  
19  end  
20  if  $NumAttributes(dex) < 3$  then  
21     $continue = False$ ;  
22  end  
23 end  
24 return dex;
```

INTERNATIONAL TRANSACTIONS
IN OPERATIONAL RESEARCH



Article

Extracting decision models for ski injury prediction from data

Sandro Radovanović✉ Marko Bohanec✉ Boris Delibašić✉

First published: 02 January 2023 | <https://doi.org/10.1111/itor.13246>

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