

Data Mining with Information Theory (DMIT)

SySc 531

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https://works.bepress.com/martin_zwick/

Terminology

- DATA MINING = **exploratory** modeling (machine learning): finding relationships between variables in data
- INFORMATION THEORY + graph theory = **Reconstructability Analysis** (RA), a.k.a discrete multivariate modeling (**DMM**)
- **OCCAM** = RA software for course

Projects

- All projects must use OCCAM
- Projects can either (a) use OCCAM alone, or (b) use OCCAM + another data mining method & compare results. (a) is standard for this course. If you do (b), state-based (SB) OCCAM analysis is not required
- Support of other methods is not part of this course

DMM section of MZ Selected Works:

resource for this course

https://works.bepress.com/martin_zwick/

Faculty & Advisors Menu Class List SelectedWorks - Martin Zwick

Portland State University PDXScholar Gallery Expert Gallery

Selected Works of Martin Zwick

Professor, Systems Science

Martin Zwick is a professor of systems science at Portland State University. After initially working in crystallography and macromolecular structure, his interests shifted to systems theory and methodology, the field now known as the study of chaos, complexity, and complex adaptive systems. His main research areas are information-theoretic modeling, theoretical biology, and systems philosophy. Scientifically, his focus is on applying systems ideas and methods to the natural and social sciences, especially to biomedical problems, the evolution of cooperation, and sustainability. Philosophically, his focus is on how systems ideas relate to classical and contemporary philosophy.

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Works About

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Search works of Martin Zwick

Discrete Multivariate Modeling (75)

Article
Graphical Models in Reconstructability Analysis and Bayesian Networks
Entropy (2021)
Marcus Harris and Martin Zwick
Reconstructability Analysis (RA) and Bayesian Networks (BN) are both probabilistic graphical modeling methodologies used in machine learning.

Download

Using Information theory to extract patterns from categorical raster data
Systems Science Faculty Publications and Presentations (2021)
David Percy
Information theory – Reconstructability Analysis (RA) implemented in the Occam software – was used to extract patterns from National Land

Download

Article
Sensitivity Analysis of an Agent-Based Simulation Model Using Reconstructability Analysis
International Journal of General Systems (2020)
Andy M. Nunes, Martin Zwick and Wayne Wakeland
Reconstructability analysis, a methodology based on information theory and graph theory, was used to perform a sensitivity analysis of an agent-based simulation model.

Download

Hypergraph Analysis of Structure Models
International Conference on Complex Systems (New England Complex Systems Society) (2020)
Cliff A. Joolyn, Teresa D. Schmidt and Martin Zwick
Theoretical discussion on the analysis of hypergraph networks; application of analysis methods to hypergraph networks derived by

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Joint Lattice of Reconstructability Analysis and Bayesian Network General Graphs
Entropy (2020)
Martin Zwick
Reconstructability Analysis (RA) and Bayesian Networks (BN) are both probabilistic graphical modeling methodologies used in machine learning.

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Reconstructability Analysis & Its Occam Implementation
Entropy (2020)
Martin Zwick
Reconstructability Analysis (RA) and Bayesian Networks (BN) are both probabilistic graphical modeling methodologies used in machine learning.

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More information on RA

- Review articles on SW page & Canvas
 - “Wholes & Parts in General Systems Methodology”
https://works.bepress.com/martin_zwick/52/
 - “An Overview of Reconstructability Analysis”
https://works.bepress.com/martin_zwick/57/
- Krippendorff, Klaus (1986). *Information Theory. Structural Models for Qualitative Data* (Quantitative Applications in the Social Sciences Monograph #62). New York: Sage Publications (at PSU Bookstore).
- *International Journal of General Systems*
- *Kybernetes*, Vol. 33, No. 5/6 2004: special RA issue

Past/present applications (some on DMM page)

- *BIOMEDICAL*

Gene-disease association, disease risk factors, gene expression, health care use & outcomes, medical records (dementia, diabetes, heart disease, prostate cancer, brain injury, primate health, surgery)

- *FINANCE-ECONOMICS-BUSINESS*

Stock market, bank loans, credit decisions, apparel analyses, market segmentation

- *SOCIAL-POLITICAL-ENVIRONMENTAL*

Socio-ecological interactions, wars, urban water use, rainfall, forest attributes

- *MATH-ENGINEERING*

Logic circuits, automata dynamics, optimization, neural networks, chip manufacturing, pattern recognition, decision analysis

- *OTHER*

Textual analysis, language analysis

Relation to other methods

- RA *related to* log-linear methods, graphical modeling, e.g., Bayesian networks, logistic regression, etc., competitive with NN, other machine learning methods
- RA is *explicitly designed for* exploratory search & has unique features not available in those methods
- RA is transparent: readily interpretable

Objectives & deliverables

ESSENTIAL GOALS

- To give you **concrete experience** of data mining
- To teach you **to use OCCAM** to analyze data
- To **analyze your data**

DELIVERABLE

- **Report & presentation** of your analysis

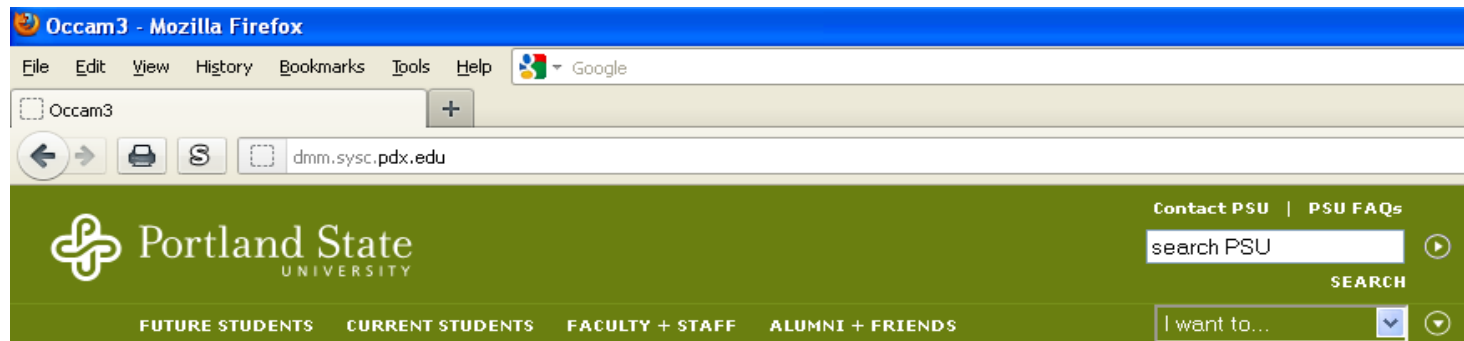
If you're ambitious, consider (this is totally optional!)

- **Comparing** RA to another method
- Making your report into a **conference or journal paper**

Course prerequisites

- YOU HAVE DATA TO ANALYZE of a type suitable for OCCAM (rectangular, adequate sample size)
- Some knowledge of probability/statistics
- Discrete Multivariate Modeling (DMM, SySc 551) NOT prerequisite.
- DMM will probably be taught in academic year 2022-2023.
- DMIT presents only theory needed to understand OCCAM output

Software tool: OCCAM: dmit.sysc.pdx.edu



Occam is a Discrete Multivariate Modeling (DMM) tool based on the methodology of Reconstructability Analysis (RA). Its typical usage is for analysis of problems involving large numbers of discrete variables. *Models* are developed which consist of one or more *components*, which are then evaluated for their fit and statistical significance. Occam can search the lattice of all possible models, or can do detailed analysis on a specific model.

In *Variable-Based Modeling (VBM)*, model components are collections of variables. In *State-Based Modeling (SBM)*, components identify one or more specific states or substates.

Occam provides a web-based interface, which allows uploading a data file, performing analysis, and viewing or downloading results.

- [Run Occam](#)
- For basic operation instructions, please see the manual: [PDF](#)
- Sample data files. You can download these to local files on your computer, then upload them via the Occam Web interface.
[A Neutral System](#)
[A Directed System](#)
- Links:
[Dr. Zwick's DMM Research Page](#)
[Systems Science Graduate Program](#)
[Occam-users mailing list \(discussion\)](#)
[Occam-news mailing list \(announcements\)](#)
- Contacts:
[Occam feedback email address](#)
[Dr. Martin Zwick, Systems Science](#)
[Joe Fusion, Graduate Assistant, Systems Science](#)

OCCAM server

- **dmit** is the OCCAM server for this course; openly accessible over the web
- If class overloads dmit, another server will be made available
- OCCAM is now open source; at <https://github.com/occam-ra/occam>

OCCAM manual

OCCAM: A Reconstructability Analysis Program

(Organizational Complexity Computation and Modeling)

Project Director: Martin Zwick

zwick@pdx.edu

Past Programmers:

Heather Alexander, Joe Fusion, Kenneth Willett¹

Systems Science Program

Portland State University

Portland OR 97207

This manual was last revised on 19 January 2021.

Occam version 3.4.1, copyright 2006-2020.

Occam User's Manual

1/19/2021

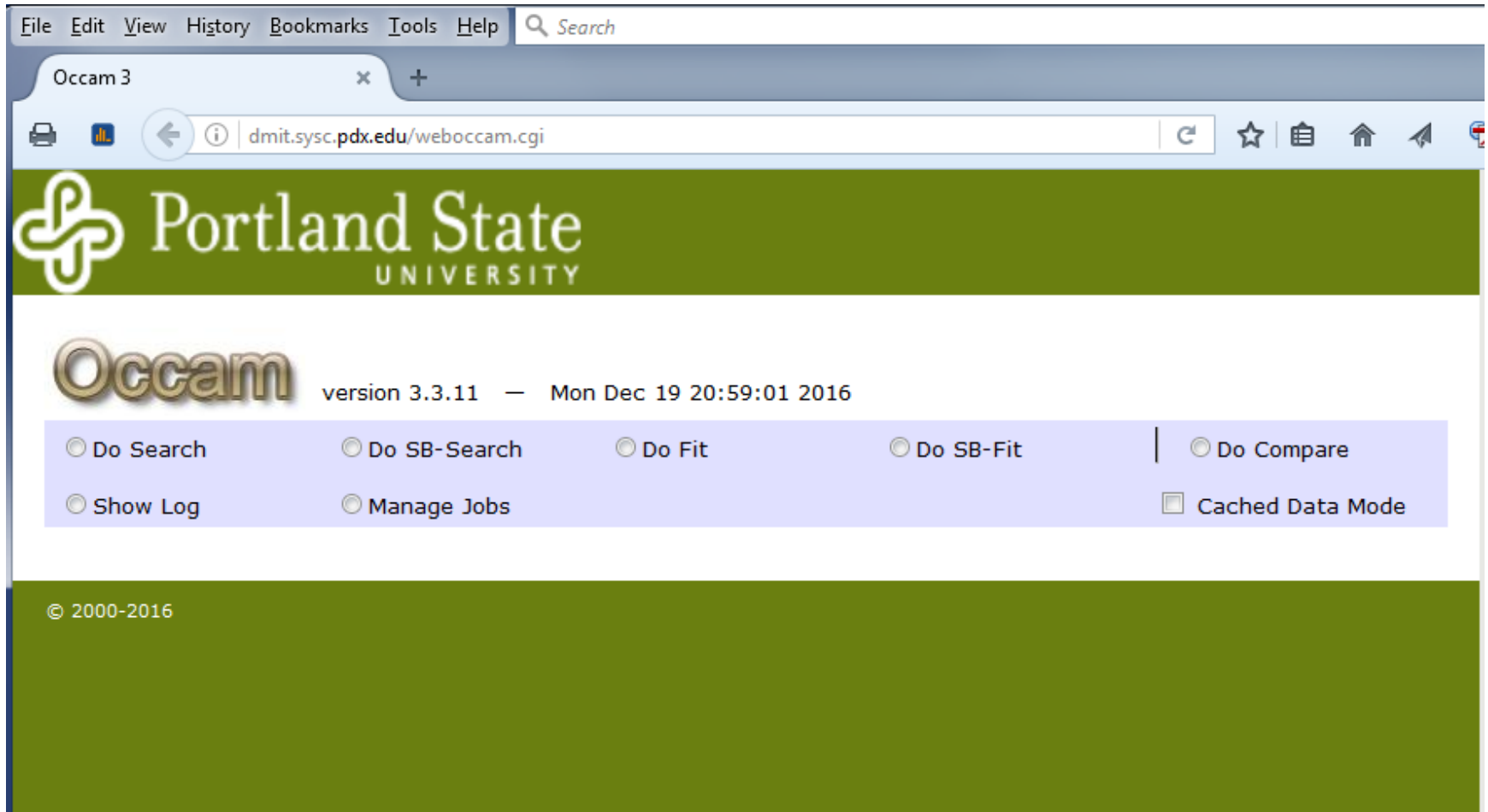
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¹ Ken Willett totally rewrote earlier versions of Occam. His version was originally called "Occam3" to distinguish it from these earlier Occam incarnations; the "3" has finally been dropped in this manual

OCCAM initial screen



OCCAM actions

- **Search** = **exploratory** modeling, examine many models, find best or good ones
(OCCAM actions Search, SB-Search)
- **Fit** = look at one model in detail & use for prediction; **confirmatory** modeling
(OCCAM actions Fit, SB-Fit)

Compare: specific to one PhD project

Show log, Manage jobs: managerial functions

RA model types ^(1/3)

- Models are
 - Variable-based (VB), *or*
 - State-based (SB)
- A VB or SB model
 - Is loopless, *or*
 - Has loops

RA model types (e.g., 4 variables: A,B,C,Z) (2/3)

- **Variable**-based

- loopless

- ABC:ABZ

- many* variables **COARSE**

- simple prediction, *feature selection*

- FAST**

- with loops

- ABC:AZ:BZ

- up to 100s variables **FINE**

- better prediction, *detailed analysis*

- SLOW** (exercise caution in runs)

- **State**-based

- < 10 variables **ULTRA-FINE**

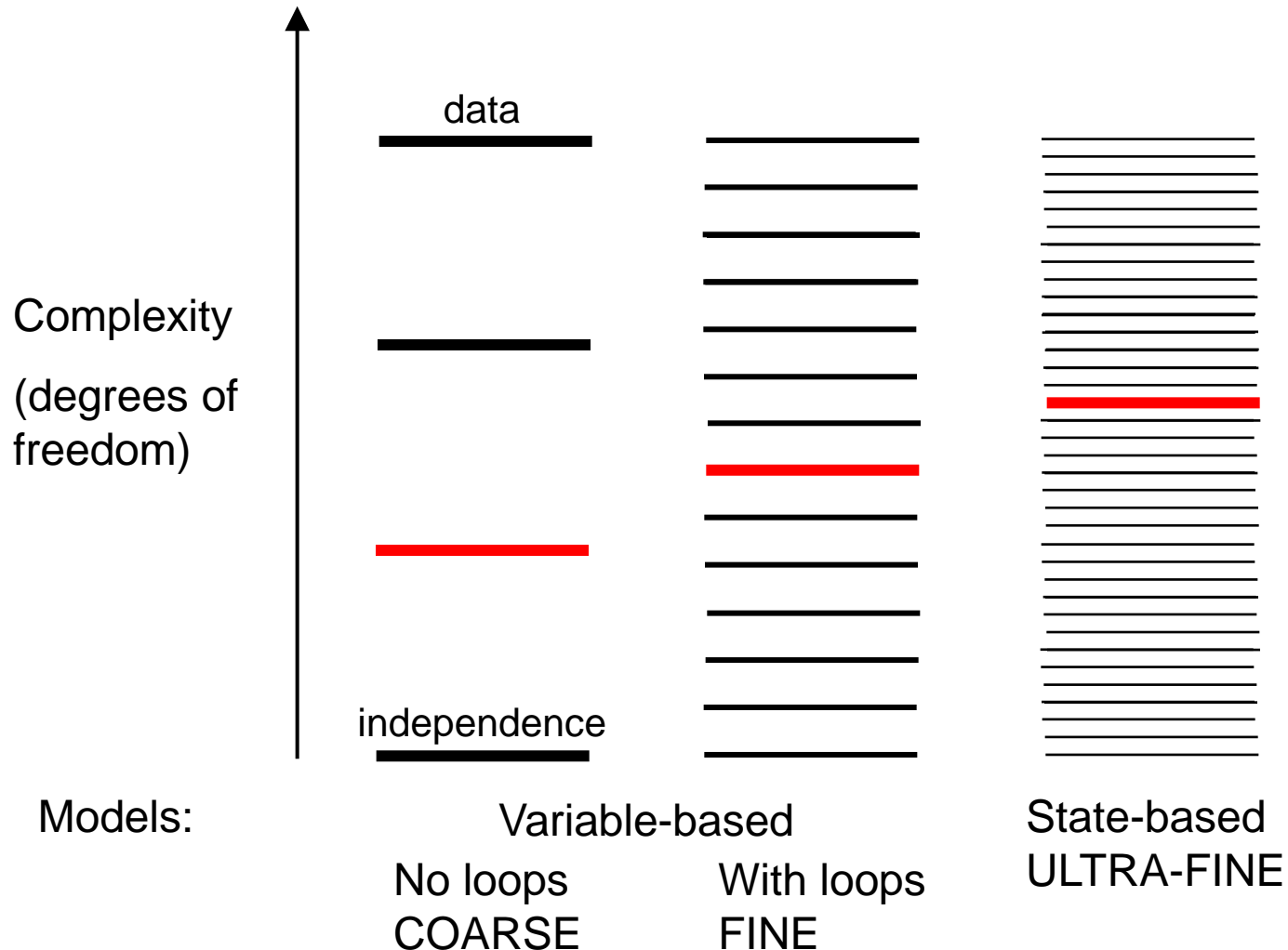
- usually w' loops

- best (most precise) prediction

- ABC:Z: A₁Z:B₂Z₁

- V. SLOW** (exercise super caution)

RA model types (3/3)



What a model **is**

- Some models:

ABC:ABZ VB loopless

ABC:AZ:BZ VB with loops

ABC:Z: $A_1Z:B_2Z_1$ SB (usually with loops)

- A model = **set of relations**, separated by colon “:”
- Relations are **predictive** (ABZ) or **not** (ABC = “IV”)
- **Multiple** predictive relations must be **integrated**
- A relation is a **joint probability** distribution

Lattice of models (e.g., 4 variables: A,B,C,Z)

- **Top** model = data = “saturated model” = most complex, e.g., ABCZ
- **Bottom** model = “independence model” = least complex
 - With IV | DV distinction (directed): ABC:Z
 - Without IV | DV distinction (neutral) : A:B:C: ...
 - Or, bottom could be uniform distribution
- **Search up** from bottom, **or down** from top,
 - Or up/down from some other model
- **Starting** model (& search direction) **vs.** **reference** model

OCCAM search (VB, SB) input page



Occam

version 3.3.11 — Fri Jan 1 15:50:55 2016

☐ Do Fit ☒ Do Search ☐ Do SB-Fit ☐ Do SB-Search ☐ Do Compare ☐ Show Log ☐ Manage Jobs

General Settings

Data File: No file selected.

Starting Model:

Composition Method: ☒ Standard ☐ Back Projection (Fourier)

Reference Model: ☒ Default ☐ Top ☐ Bottom ☐ Starting Model

Search Settings

Models to Consider: ☐ All ☒ Loopless ☐ Disjoint ☐ Chain

Search Direction: ☒ Default ☐ Up ☐ Down

During Search, Sort By: ☒ BIC ☐ AIC ☐ Information ☐ Alpha ☐ % Correct

When Searching, Prefer: ☒ Larger Values ☐ Smaller Values

Search Width:

Search Levels: (leave blank to use settings from data file)

Report Settings

In Report, Sort By: ☒ Information ☐ Alpha ☐ dDF ☐ Level ☐ % Correct ☐ BIC ☐ AIC

In Report, Sort: ☒ Descending ☐ Ascending

Include in Report: ☒ H ☒ dLR ☒ Alpha ☒ % dH(DV) ☒ dAIC ☒ dBIC

☐ BP-based Transmission ☒ Incremental Alpha

☒ % Correct ☒ % Coverage of Data ☒ % Missing in Test

☐ Return data in spreadsheet format

☒ Print option settings ☐ (but don't print variable definitions)

☐ Use inverse notation for models

Run in Background, Email Results To:

Subject line for email (optional):

Variables & cases

- Variables: so far up to about 500 IVs
Need at least 5
Best is bigger, but not too big (>10 , <100)
IV/DV (input/output) distinction: directed
No distinction: neutral This course: **directed** only
- Will usually (not always) name the DV “Z” (or “X”)
- Cases (sample size): so far up to 6.5×10^6
Need at least 100
Best is bigger, but not too big ($>1K$, $<<1M$)

Data (e.g., IVs = A,B,C; DV = Z)

- Contingency table or No frequency, just frequency (A_i, B_j, C_k, Z_l) cases X variables

				frequency
A ₀	B ₀	C ₀	Z ₀	13
A ₀	B ₀	C ₀	Z ₁	2
A ₀	B ₀	C ₁	Z ₀	9
A ₀	B ₀	C ₁	Z ₁	11
...

	A	B	C	Z
case ₁	A ₀	B ₀	C ₀	Z ₀
case ₂	A ₁	B ₂	C ₃	Z ₁
...				
case _N	A ₀	B ₀	C ₀	Z ₀

- Cases = individuals, instances, time or space values
- Variables = IVs & DV are nominal

If continuous, bin (e.g., with Excel binning program)

(In *variants* of standard RA, DV can be continuous)

Sample input file: weisdorf.txt) (for demo#1)

```

:action
search

:nominal
  season,      2,1,a
  absentee,    2,0,b
  sqfeet,      8,1,c
  valued,     12,1,d
  yrbuilt,    12,1,e
  zip,        40,0,f
  ccf,        16,0,w
  normccf,    16,2,x

:no-frequency

:data
0      0      1      2      9      39      1      1
0      1      2      3      9      19      0      0
0      1      1      3      5      19      2      2
0      1      1      4      7      19      0      0
0      0      1      2      0      1      3      2
0      1      1      1      0      1      3      2
0      1      1      3      9      39      1      1
0      1      3      5      7      19      1      0
0      1      1      2      1      39      0      0
0      0      0      1      5      39      0      0
0      1      1      1      1      39      1      1
0      1      2      3      6      19      1      1
0      0      2      2      0      1      1      1
0      1      2      4      5      19      2      2
0      1      2      3      1      39      2      2
0      1      2      3      6      19      2      2
0      1      0      1      3      39      1      0
0      1      1      3      5      39      1      1
0      1      0      2      0      39      1      1
0      1      1      2      1      39      0      0
0      1      1      4      3      19      2      2
```

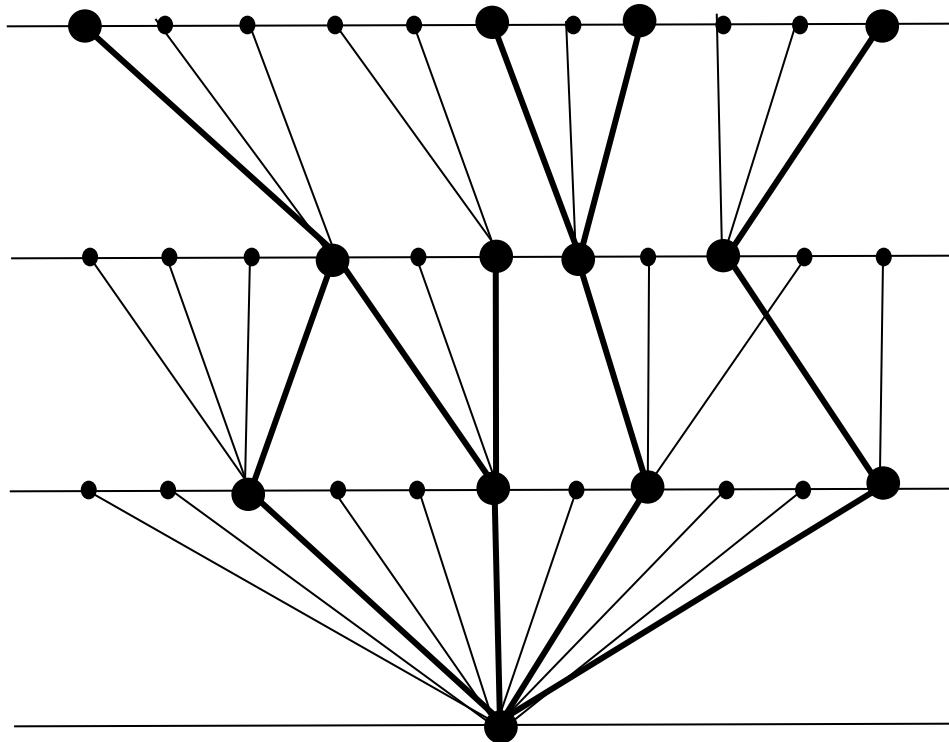
Preparing an OCCAM input file

- Include all variables you have (you can always tell OCCAM to ignore some); make DV the *last* variable
- In binning variables (by yourself or with **utility program**), **3 bins** is a reasonable default, but it's better to use **more bins** (e.g., **12**) since you can rebin (aggregate bins) on the fly in the OCCAM input file; see Appendix of OCCAM manual on rebinning
- Code **missing values** as “.”
- Use **comments** “#” in input file

OCCAM search output (1/4)

- Search many models: select best w ('width') models at each of l 'levels'
- Output all selected $w \cdot l$ models
- OCCAM summarizes the best of these

OCCAM search output (2/4)



Upwards
search,
increasing
complexity,
width=4,
levels=3

Independence model

OCCAM search output (3/4)

- OCCAM summarizes:
- Of width*levels models found in search, it indicates the **best three** by different criteria:
 - (i) highest Δ **BIC**
 - (ii) highest Δ **AIC**
 - (iii) highest information with OK **p-values**
(both **cumulative** & **incremental**)

Search output for weisdorf.txt

VB models without loops (search sort on bic)(demo#1)

```
state space size      33192
Sample Size           158018
H(data)               9.61708
H(IV)                 7.46711
H(DV)                 2.35084
T(IV:DV)              0.200864
IVs in use (4)        A C D E
DV                    X
```

Searching levels:

```
1 : 4 new models, 3 kept; 5 total models, 4 total kept; 0 kb memory used; 0.0 seconds, 0.0 total
2 : 6 new models, 3 kept; 11 total models, 7 total kept; 828 kb memory used; 0.1 seconds, 0.1 total
3 : 3 new models, 3 kept; 14 total models, 10 total kept; 2096 kb memory used; 0.1 seconds, 0.1 total
4 : 1 new models, 1 kept; 15 total models, 11 total kept; 2592 kb memory used; 0.1 seconds, 0.2 total
5 : 0 new models, 0 kept; 15 total models, 11 total kept; 2592 kb memory used; 0.0 seconds, 0.2 total
```

ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH(DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover
11	ACDEX	4	9.6171	31665	44001.1153	0.0000	1.000000000	8.5444	-19328.8847	-335043.6345	1.0000	8	39.7733	52.9356
10*	IV:ACEX	3	9.6613	2865	34314.0074	0.0000	0.77984404	6.6633	28584.0074	18.6274	0.0000	5	39.1474	98.9583
9*	IV:ACDX	3	9.6654	2625	33417.9888	0.0000	0.75948049	6.4893	28167.9888	1995.5202	0.0000	6	39.1848	77.2727
8*	IV:ADEX	3	9.6676	3945	32943.0006	0.0000	0.74868558	6.3970	25053.0006	-14280.4808	0.0000	5	39.2012	100.0000
7*	IV:ACX	2	9.6785	225	30539.7263	0.0000	0.69406710	5.9304	30089.7263	27846.3718	0.0000	3	38.9595	100.0000
6*	IV:ADX	2	9.6921	315	27574.9068	0.0000	0.62668654	5.3546	26944.9068	23804.2106	0.0000	2	38.9013	100.0000
5*	IV:AEX	2	9.7456	345	15841.4381	0.0000	0.36002356	3.0762	15151.4381	11711.6279	0.0000	3	38.7437	100.0000
4*	IV:CX	1	9.7471	105	15514.9322	0.0000	0.35260316	3.0128	15304.9322	14258.0335	0.0000	1	38.7753	100.0000
3*	IV:AX	1	9.7606	15	12561.7145	0.0000	0.28548628	2.4393	12531.7145	12382.1576	0.0000	1	38.7437	100.0000
2*	IV:DX	1	9.7617	150	12309.9942	0.0000	0.27976550	2.3904	12009.9942	10514.4246	0.0000	1	38.8070	100.0000
1*	IV:X	0	9.8179	0	0.0000	1.0000	0.000000000	0.0000	0.0000	0.0000	0.0000	0	38.7437	100.0000
ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH(DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover

Best Model(s) by dBIC:

```
7* IV:ACX 2 9.6785 225 30539.7263 0.0000 0.69406710 5.9304 30089.7263 27846.3718 0.0000 3 38.9595 100.0000
```

Best Model(s) by dAIC:

```
7* IV:ACX 2 9.6785 225 30539.7263 0.0000 0.69406710 5.9304 30089.7263 27846.3718 0.0000 3 38.9595 100.0000
```

Best Model(s) by Information, with all Inc. Alpha < 0.05:

```
10* IV:ACEX 3 9.6613 2865 34314.0074 0.0000 0.77984404 6.6633 28584.0074 18.6274 0.0000 5 39.1474 98.9583
```

Sample input file: dementia05.txt (for demo#2,#3)

```
#Fifth test set of OHSU data 20 June 2012
#Corrected transform of variable I rs12248379
#Corrected transform of APOE
#Updated imputed data
#Deleted var I and dropped records with no var C data
#Added stats on missing. Blank = none missing
```

```
:nominal
ID ,0,0,ID
APOE ,2,1,AP
Gender ,2,1,SX
Education ,3,1,ED
AgeLastExam ,3,1,AG
rs1801133 ,3,1,A
rs3818361 ,4,1,B # missing 3
rs7561528 ,3,1,C
rs744373 ,3,1,D
rs6943822 ,3,1,E
rs4298437 ,3,1,F
rs7012010 ,3,1,G
rs11136000 ,3,1,H
rs10786998 ,4,1,J # missing 9
rs11193130 ,4,1,K # missing 11
rs610932 ,3,1,L
rs3851179 ,3,1,M
rs3764650 ,4,1,N # missing 2
rs3865444 ,4,1,P # missing 9
CaseControl ,2,2,Z
```

```
:no-frequency
```

```
:data
#IndID APOE GENDER EDU ALE A B C D E F G H J
101 0 0 2 2 1 1 0 1 2 2 1 1 2
103 0 0 2 1 0 2 2 0 1 1 1 2 2
111 0 1 2 1 2 2 1 1 0 1 1 2 1
112 0 0 2 2 2 2 1 1 1 2 1 1 0
118 0 1 0 2 2 2 2 0 0 1 1 1 .
120 0 1 2 2 1 2 1 1 0 1 1 2 1
121 0 0 2 2 2 2 1 1 2 0 0 0 2
122 0 0 1 2 2 1 2 1 2 0 0 2 2
123 0 0 2 2 2 2 2 0 1 1 0 0 2
126 0 0 2 2 2 2 2 0 1 1 2 2 2
127 0 1 2 2 2 2 1 1 1 1 1 2 2
128 0 0 2 2 2 1 2 1 0 1 1 2 .
129 1 1 2 2 2 2 1 0 1 0 1 2 0
132 0 0 2 2 2 2 1 0 0 1 1 2 1
134 0 1 2 2 2 0 2 0 0 1 1 1 0
135 0 0 2 2 2 1 1 0 0 2 1 1 0
```

Search output for dementia05.txt

VB models with loops (search sort on [info](#))(demo#2)

ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH(DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover
22	IV:ApZ:EdCZ:EdKZ:LZ	7	9.5221	20	120.2026	0.0000	0.20476589	20.4766	80.2026	-0.7921	0.0505	19	72.4057	52.7778
21	IV:ApZ:EdCZ:EdKZ:BZ	7	9.5224	21	120.0402	0.0000	0.20448919	20.4489	78.0402	-7.0043	0.1093	18	72.6415	38.5417
20	IV:ApZ:EdKZ:EdLZ:CZ	7	9.5224	20	120.0236	0.0000	0.20446093	20.4461	80.0236	-0.9711	0.0890	17	71.9340	52.7778
19	IV:ApZ:EdCZ:EdKZ	6	9.5323	18	114.2291	0.0000	0.19459005	19.4590	78.2291	5.3339	0.1469	16	71.6981	76.3889
18	IV:ApZ:EdKZ:BZ:CZ	6	9.5352	17	112.5147	0.0000	0.19166949	19.1669	78.5147	9.6692	0.1656	16	72.1698	38.5417
17	IV:ApZ:EdKZ:CZ:LZ	6	9.5361	16	111.9806	0.0000	0.19075974	19.0760	79.9806	15.1849	0.0053	14	72.4057	52.7778
16*	IV:ApZ:EdKZ:CZ	5	9.5438	14	107.4549	0.0000	0.18305008	18.3050	79.4549	22.7586	0.0037	13	71.2264	76.3889
15*	IV:ApZ:EdJZ:CZ	5	9.5536	14	101.7185	0.0000	0.17327808	17.3278	73.7185	17.0222	0.0434	11	70.7547	76.3889
14	IV:ApZ:EdKZ:LZ	5	9.5540	14	101.4868	0.0000	0.17288344	17.2883	73.4868	16.7905	0.0737	13	71.6981	76.3889
13*	IV:ApZ:EdKZ	4	9.5628	12	96.2708	0.0000	0.16399792	16.3998	72.2708	23.6740	0.0274	10	70.5189	91.6667
12*	IV:ApZ:EdZ:CZ:KZ	4	9.5665	8	94.1440	0.0000	0.16037485	16.0375	78.1440	45.7461	0.0007	8	70.0472	76.3889
11*	IV:ApZ:EdZ:CZ:JZ	4	9.5756	8	88.7544	0.0000	0.15119366	15.1194	72.7544	40.3565	0.0301	9	69.5755	76.3889
10*	IV:ApZ:EdZ:KZ	3	9.5870	6	82.0689	0.0000	0.13980489	13.9805	70.0689	45.7705	0.0003	5	69.8113	91.6667
9*	IV:ApZ:EdZ:CZ	3	9.5908	5	79.8373	0.0000	0.13600335	13.6003	69.8373	49.5886	0.0010	6	69.5755	100.0000
8*	IV:ApZ:CZ:KZ	3	9.5910	6	79.7227	0.0000	0.13580807	13.5808	67.7227	43.4243	0.0009	5	68.6321	87.5000
7*	IV:ApZ:EdZ	2	9.6133	3	66.5901	0.0000	0.11343675	11.3437	60.5901	48.4409	0.0000	2	69.5755	100.0000
6*	IV:ApZ:CZ	2	9.6144	3	65.9506	0.0000	0.11234732	11.2347	59.9506	47.8014	0.0000	3	67.9245	100.0000
5*	IV:ApZ:KZ	2	9.6150	4	65.6244	0.0000	0.11179159	11.1792	57.6244	41.4255	0.0024	4	66.9811	100.0000
4*	IV:ApZ	1	9.6396	1	51.1652	0.0000	0.08716028	8.7160	49.1652	45.1155	0.0000	1	66.9811	100.0000
3*	IV:CZ	1	9.6998	2	15.7735	0.0004	0.02687026	2.6870	11.7735	3.6740	0.0004	1	58.0189	100.0000
2*	IV:EdZ	1	9.7009	2	15.1356	0.0005	0.02578359	2.5784	11.1356	3.0361	0.0005	1	56.3679	100.0000
1*	IV:Z	0	9.7266	0	0.0000	1.0000	0.00000000	0.0000	0.0000	0.0000	0.0000	0	52.1226	100.0000
ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH(DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover

Best Model(s) by dBIC:

9*	IV:ApZ:EdZ:CZ	3	9.5908	5	79.8373	0.0000	0.13600335	13.6003	69.8373	49.5886	0.0010	6	69.5755	100.0000
----	---------------	---	--------	---	---------	--------	------------	---------	---------	---------	--------	---	---------	----------

Best Model(s) by dAIC:

22	IV:ApZ:EdCZ:EdKZ:LZ	7	9.5221	20	120.2026	0.0000	0.20476589	20.4766	80.2026	-0.7921	0.0505	19	72.4057	52.7778
----	---------------------	---	--------	----	----------	--------	------------	---------	---------	---------	--------	----	---------	---------

Best Model(s) by Information, with all Inc. Alpha < 0.05:

16*	IV:ApZ:EdKZ:CZ	5	9.5438	14	107.4549	0.0000	0.18305008	18.3050	79.4549	22.7586	0.0037	13	71.2264	76.3889
-----	----------------	---	--------	----	----------	--------	------------	---------	---------	---------	--------	----	---------	---------

Search output (4/4)

Goodness measures for best models selected using BIC, AIC, p-value criteria:

- Reduction of DV uncertainty $\% \Delta H(DV \mid IV)$,
- Model complexity, df (degrees of freedom)
- Predictive accuracy: %correct

Search output for dementia05.txt

Models selected by BIC/AIC/p-value (sort on [info](#))

<u>Criterion</u>	<u>model</u>	<u>%ΔH</u>	<u>df</u>	<u>%c</u>
BIC	IV:ApZ:EdZ:CZ	14	5	70
p-value	IV:ApZ:EdKZ:CZ	18	14	71
AIC	IV:ApZ:EdCZ:EdKZ:LZ	20	20	72
SB BIC	IV:Ap ₀ Ed ₀ Z:Ap ₁ Z:C ₂ Z:Z	14	3	70

IV = ApEdCKL... (all independent variables)

OCCAM **Fit** (VB, SB) input page

File Edit View History Bookmarks Tools Help Search

Occam 3

dmit.sysc.pdx.edu/weboccam.cgi?action=fit&cached=

 **Portland State**
UNIVERSITY

Occam version 3.3.11 — Mon Dec 19 21:06:39 2016

☐ Do Search ☐ Do SB-Search ☒ Do Fit ☐ Do SB-Fit ☐ Do Compare

☐ Show Log ☐ Manage Jobs ☐ Cached Data Mode

Data Settings

Data File: No file selected.

Fit Settings

Model to Fit:

Optional default model:

For directed systems:

Default ("negative") DV state (*after rebinning*) for confusion matrices:

☐ Calculate expected DV

For neutral systems:

☒ Omit table showing all states for entire model; ☒ also omit tables for IVI variables

Hypergraph Display Settings

Hypergraph Layout Style: ☒ Fruchterman-Reingold ☐ Reingold-Tilford ☐ Sugiyama ☐ Kamada-Kawai ☐ Bipartite

☒ Generate graph images

☐ Generate Gephi files

☒ Hide IV/IVI components

☐ Use full variable names in graph labels

Output Settings

☐ Return data in CSV format (if hypergraph rendering enabled, return ZIP format containing CSV, PDF, and Gephi files)

☒ Print option settings ☐ (but don't print variable definitions)

Run in Background, Email Results To:

Subject line for email (optional):

Fit output

- A model is a *calculated conditional probability* distribution, $p_{\text{model}}(\text{DV} \mid \text{IV})$,
e.g., $p_{\text{ABC:AZ:BZ}}(Z_i \mid A_i, B_j, C_k)$
- Predict DV (Z) from IVs (A,B,C), using this conditional p distribution (*stochastic*)

Fit output for dementia05.txt

model IV:ApZ:EdZ:CZ (has loop) (demo#3)

Conditional DV (D) (%) for each IV composite state for the Model IV:ApZ:EdZ:CZ.
IV order: ApEdC (APOE; Education; rs7561528).

IV			Data			Model							
			obs. p(DV IV)			calc. q(DV IV)							
Ap	Ed	C	freq	Z=0	Z=1	Z=0	Z=1	rule	#correct	%correct	p(rule)	p(margin)	
0	0	0	6.000	33.333	66.667	16.719	83.281	1	4.000	66.667	0.103	0.083	
0	0	1	4.000	0.000	100.000	21.075	78.925	1	4.000	100.000	0.247	0.214	
0	0	2	7.000	14.286	85.714	35.284	64.716	1	6.000	85.714	0.436	0.372	
0	1	0	8.000	50.000	50.000	52.532	47.468	0	4.000	50.000	0.886	0.981	
0	1	1	40.000	62.500	37.500	59.546	40.454	0	25.000	62.500	0.227	0.347	
0	1	2	44.000	72.727	27.273	75.034	24.966	0	32.000	72.727	0.001	0.002	
0	2	0	14.000	42.857	57.143	55.306	44.694	0	6.000	42.857	0.691	0.811	
0	2	1	86.000	60.465	39.535	62.205	37.795	0	52.000	60.465	0.023	0.061	
0	2	2	68.000	83.824	16.176	77.067	22.933	0	57.000	83.824	0.000	0.000	
1	0	0	3.000	0.000	100.000	3.984	96.016	1	3.000	100.000	0.111	0.095	
1	0	1	5.000	20.000	80.000	5.230	94.770	1	4.000	80.000	0.045	0.036	
1	0	2	3.000	33.333	66.667	10.127	89.873	1	2.000	66.667	0.167	0.146	
1	1	0	8.000	25.000	75.000	18.614	81.386	1	6.000	75.000	0.076	0.058	
1	1	1	19.000	26.316	73.684	23.325	76.675	1	14.000	73.684	0.020	0.012	
1	1	2	21.000	33.333	66.667	38.315	61.685	1	14.000	66.667	0.284	0.206	
1	2	0	12.000	25.000	75.000	20.366	79.634	1	9.000	75.000	0.040	0.028	
1	2	1	40.000	25.000	75.000	25.381	74.619	1	30.000	75.000	0.002	0.001	
1	2	2	36.000	36.111	63.889	40.986	59.014	1	23.000	63.889	0.280	0.181	
			424.000	52.123	47.877	52.123	47.877	0	295.000	69.575			
			freq	Z=0	Z=1	Z=0	Z=1	rule	#correct	%correct	p(rule)	p(margin)	

* Rule selected using the independence model.

Input file for SB-search (for demo#4)

dementia05ApEdC.txt: reduce #IVs to 3

```
#Fifth test set of OHSU data 20 June 2012
#Corrected transform of variable I rs12248379
#Corrected transform of APOE
#Updated imputed data
#Deleted var I and dropped records with no var C data
#Added stats on missing. Blank = none missing
```

```
:nominal
ID ,0,0,ID
APOE ,2,1,AP
Gender ,2,0,SX
Education ,3,1,ED
AgeLastExam ,3,0,AG
rs1801133 ,3,0,A
rs3818361 ,4,0,B # missing 3
rs7561528 ,3,1,C
rs744373 ,3,0,D
rs6943822 ,3,0,E
rs4298437 ,3,0,F
rs7012010 ,3,0,G
rs11136000 ,3,0,H
rs10786998 ,4,0,J # missing 9
rs11193130 ,4,0,K # missing 11
rs610932 ,3,0,L
rs3851179 ,3,0,M
rs3764650 ,4,0,N # missing 2
rs3865444 ,4,0,P # missing 9
CaseControl ,2,2,Z
```

```
:no-frequency
```

```
:data
#IndID APOE GENDER EDU ALE A B C D E F G H J K
101 0 0 2 2 1 1 0 1 2 2 1 1 2 0
103 0 0 2 1 0 2 2 0 1 1 1 2 2 0
111 0 1 2 1 2 2 1 1 0 1 1 2 1 1
112 0 0 2 2 2 2 1 1 1 2 1 1 0 2
118 0 1 0 2 2 2 2 0 0 1 1 1 . .
120 0 1 2 2 2 2 1 1 0 1 1 2 . 1
121 0 0 2 2 2 2 1 1 2 0 0 0 2 0
122 0 0 1 2 2 2 1 1 2 0 0 2 2 0
123 0 0 2 2 2 2 2 0 1 1 0 0 2 0
126 0 0 2 2 2 2 2 0 1 1 2 2 2 0
127 0 1 2 2 0 2 1 1 1 1 1 2 2 0
128 0 0 2 2 1 2 1 1 0 1 1 2 . 2
129 1 1 2 2 2 2 1 0 1 0 1 2 0 2
132 0 0 2 2 2 2 1 0 0 1 1 2 1 1
134 0 1 2 2 0 0 2 0 0 1 1 1 0 2
135 0 0 2 2 2 1 1 0 0 2 1 1 0 2
```

SB search output (demo#4)

ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH (DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover
16	IV:Ap0Ed0C0Z:Ap0Ed2C2Z:Ap0Ed0Z:Ap1Z:C2Z:Z	5	4.3897	5	86.7978	0.0000	0.95071864	14.7861	76.7978	56.5491	0.0949	12	69.5755	100.0000
15	IV:Ap0Ed0C0Z:Ap0Ed0Z:Ap0C0Z:Ap1Z:C2Z:Z	5	4.3906	5	86.2578	0.0000	0.94480434	14.6941	76.2578	56.0091	0.1337	12	70.0472	100.0000
14	IV:Ap0Ed2C2Z:Ap1Ed0C0Z:Ap0Ed0Z:Ap1Z:C2Z:Z	5	4.3906	5	86.2410	0.0000	0.94462025	14.6912	76.2410	55.9923	0.1962	13	69.5755	100.0000
13*	IV:Ap0Ed2C2Z:Ap0Ed0Z:Ap1Z:C2Z:Z	4	4.3935	4	84.5686	0.0000	0.92630198	14.4063	76.5686	60.3697	0.0337	9	69.5755	100.0000
12	IV:Ap0Ed0C0Z:Ap0Ed0Z:Ap1Z:C2Z:Z	4	4.3944	4	84.0051	0.0000	0.92012989	14.3103	76.0051	59.8062	0.1044	10	69.5755	100.0000
11	IV:Ap0Ed0Z:Ap0C2Z:Ap1Z:Ed2C2Z:Z	4	4.3951	4	83.6256	0.0000	0.91597252	14.2457	75.6256	59.4266	0.0567	8	69.5755	100.0000
10*	IV:Ap0Ed0Z:Ap1Z:C2Z:Z	3	4.3989	3	81.3650	0.0000	0.89121192	13.8606	75.3650	63.2158	0.0002	7	69.5755	100.0000
9*	IV:Ap0Ed2C2Z:Ap0Ed0Z:Ap1Z:Z	3	4.4011	3	80.0645	0.0000	0.87696704	13.6390	74.0645	61.9153	0.0002	6	69.5755	100.0000
8*	IV:Ap0Ed0Z:Ap0C2Z:Ap1Z:Z	3	4.4013	3	79.9909	0.0000	0.87616134	13.6265	73.9909	61.8417	0.0004	7	69.5755	100.0000
7*	IV:Ap0Ed0Z:Ap1Z:Z	2	4.4216	2	68.0475	0.0000	0.74534205	11.5919	64.0475	55.9480	0.0000	4	69.5755	100.0000
6*	IV:Ap0Ed2C2Z:Ap1Z:Z	2	4.4232	2	67.1062	0.0000	0.73503174	11.4316	63.1062	55.0067	0.0000	2	66.9811	100.0000
5*	IV:Ap1Z:Ed0Z:Z	2	4.4243	2	66.4783	0.0000	0.72815386	11.3246	62.4783	54.3788	0.0001	4	69.5755	100.0000
4*	IV:Ap1Z:Z	1	4.4504	1	51.0910	0.0000	0.55961325	8.7034	49.0910	45.0413	0.0000	1	66.9811	100.0000
3*	IV:Ap0C2Z:Z	1	4.4727	1	37.9865	0.0000	0.41607561	6.4710	35.9865	31.9367	0.0000	1	62.2642	100.0000
2*	IV:Ap0Ed2C2Z:Z	1	4.4770	1	35.4733	0.0000	0.38854880	6.0429	33.4733	29.4236	0.0000	1	58.7264	100.0000
1*	IV:Z	0	4.5374	0	0.0000	1.0000	0.00000000	0.0000	0.0000	0.0000	0.0000	0	52.1226	100.0000

ID	MODEL	Level	H	dDF	dLR	Alpha	Inf	%dH (DV)	dAIC	dBIC	Inc.Alpha	Prog.	%C(Data)	%cover
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Best Model(s) by dBIC:

10*	IV:Ap0Ed0Z:Ap1Z:C2Z:Z	3	4.3989	3	81.3650	0.0000	0.89121192	13.8606	75.3650	63.2158	0.0002	7	69.5755	100.0000
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Best Model(s) by dAIC:

16	IV:Ap0Ed0C0Z:Ap0Ed2C2Z:Ap0Ed0Z:Ap1Z:C2Z:Z	5	4.3897	5	86.7978	0.0000	0.95071864	14.7861	76.7978	56.5491	0.0949	12	69.5755	100.0000
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Best Model(s) by Information, with all Inc. Alpha < 0.05:

13*	IV:Ap0Ed2C2Z:Ap0Ed0Z:Ap1Z:C2Z:Z	4	4.3935	4	84.5686	0.0000	0.92630198	14.4063	76.5686	60.3697	0.0337	9	69.5755	100.0000
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SB-search output

- Example of a best model from SB-Search:

Best model by BIC criterion

IV:Z: $Ap_0Ed_0Z : Ap_1Z : C_2Z$ (note interaction effect)

For this data, get about same uncertainty reduction & %correct, but **2 df simpler**

In other data often get **higher uncertainty reduction & %correct** for about same df

Non-standard or enhanced RA

Non-standard

- Time series analysis
- Continuous DVs (not for this course)
- Set-theoretic data (not for this course)

Enhanced

- Validation (training-test data splits)
- Inter-method comparison

Time series analysis

Can similarly do spatial (e.g., GIS) analysis

	A	B	C		A	B	C		U	V	W	X	Y	Z
t-4	--	--	--		--	--	--		--	--	--	--	--	--
t-3	--	--	--		0	1	2		--	--	--	--	--	--
t-2	--	--	--		3	4	5		0	1	2	3	4	5
t-1	U	V	W		6	7	8		3	4	5	6	7	8
t	X	Y	Z		9	10	11		6	7	8	9	10	11

mask original data
(numbers label
variables)

transformed data
 $XYZ(t) = ABC(t)$
 $UVW(t) = ABC(t-1)$

Enhanced RA (for directed systems)

(Totally optional for this course)

Validation: **training/test** data **splits**
or 3-way splits; 5- or 10-fold validation

Comparison with other data mining **methods**
e.g., Logistic Regression, Support Vector Machines,
Bayesian Networks, ...

RA framework (1/2)

bold = typical RA use; **blue** = in OCCAM; **red** = other pgms

1. <i>VARIABLE</i>	nominal (discrete: binary or multi-valued)
	ordinal (discrete)
	quantitative (bin continuous values for IVs)
2. <i>SYSTEM</i>	directed (deterministic/stochastic) (<i>supervised learning</i>)
	neutral (<i>unsupervised learning</i>)
3. <i>DATA</i>	Information-theoretic (IRA)
	frequency/probability distribution
	function ('k-systems' & 'u-systems' RA)
	set-theoretic (SRA) mapping, relation

RA framework (2/2)

bold = typical RA use; **blue** = in OCCAM; **red** = other pgms

<i>4. PROBLEM</i>	reconstruction (decomposition)
	confirmatory
	exploratory
	exhaustive (look at all models)
	heuristic (search lattice of models)
	identification (composition)
<i>5. METHOD</i>	variable-based (VB)
	state-based (SB)
	latent variable-based (LVB)

Questions?

LOOKING FORWARD
TO AN EXCITING, CHALLENGING, &
PRODUCTIVE COURSE !!