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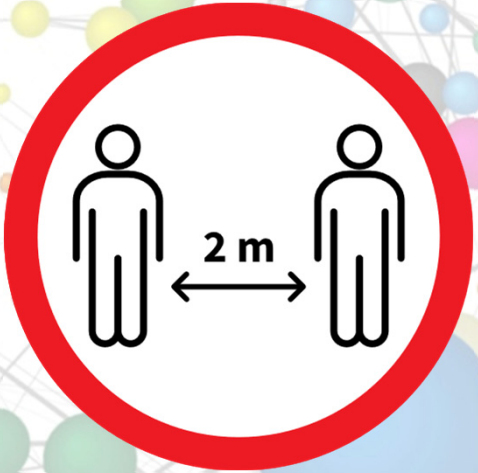

not enough time

Spatial ~~and Temporal Modeling~~ with Bayesian Networks

Reasoning About Distances in Populations

April 30, 2020

Agenda

Introduction & Resources

Motivation

- What is our distance?
- What should be our distance?

Tutorial

- Distribution of distances in a unit square
- Distribution of distances in the continental U.S.
- BayesiaLab & GIS Mapping
- Spatial Learning & Optimization

Introduction

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Bayesian Networks & BayesiaLab

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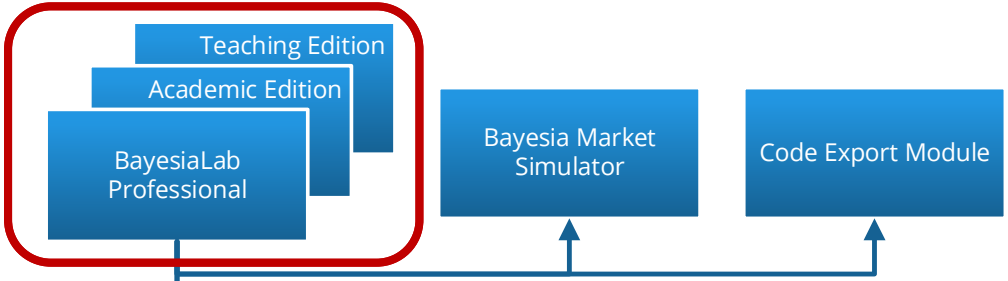
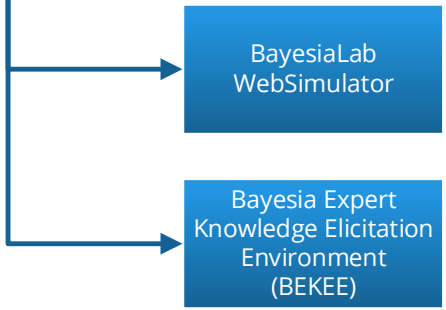
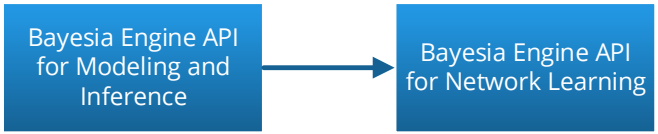
Desktop Software



Web Application



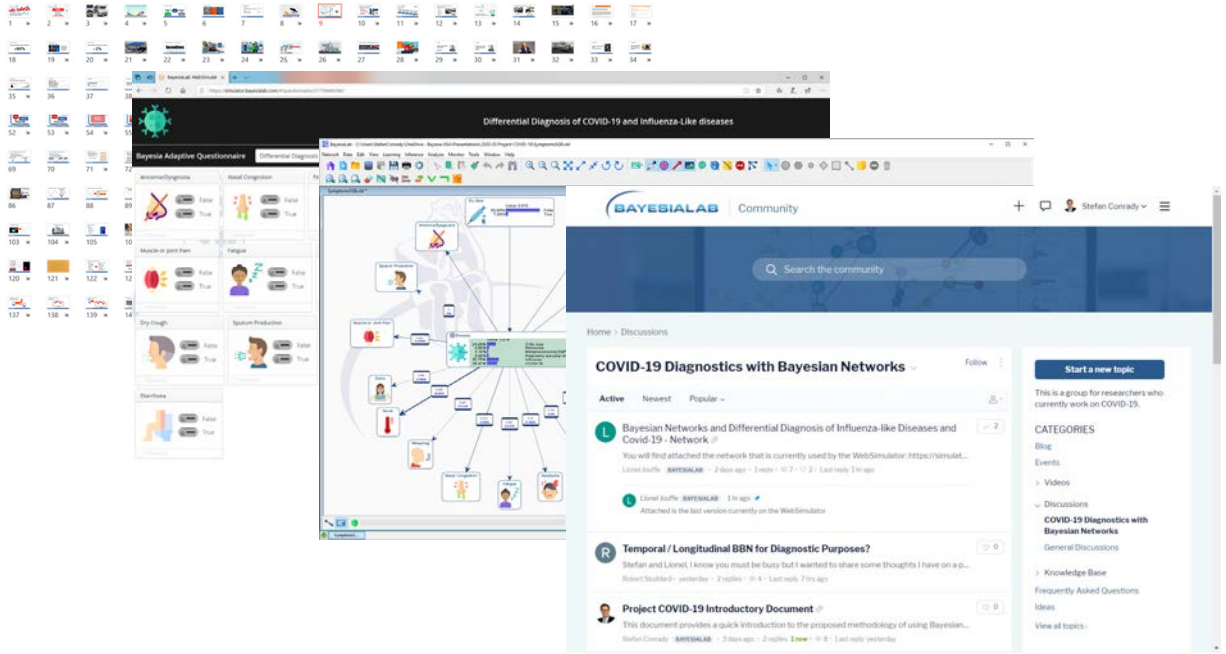
API



Resources

Webinar Materials Available in the BayesiaLab Community

- Slides
- Network Model
- Webinar Recording
- Q&A



COVID-19 Diagnostics v

https://forum.bayesia.us/category/covid

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Home > Discussions

COVID-19 Diagnostics with Bayesian Networks

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Call for Expertise — Help Improve the COVID-19 Knowledge Base 2

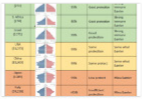
Please join our volunteer group of infectious disease specialists, clinicians, epidemiologists, biost...

Stefan Conrady BAYESIALAB · 4 days ago · 2 replies · 101 · 2 · Last reply 3 days ago

Oral polio vaccine as infection control? 2

Chinese study theorizes that oral polio vaccine can reduce probably of Covid19 in under-30 dem...

Kurt Schulzke · 4 days ago · 2 replies · 5 · 2 · Last reply 4 days ago



Start a new topic

This is a group for researchers who currently work on COVID-19.

CATEGORIES

- Blog
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- Videos
- Discussions
  - **COVID-19 Diagnostics with Bayesian Networks**
  - General Discussions
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View all topics

Please see Part 1-3 of this webinar series

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Reasoning Under Uncertainty (Part 2) — Differential Diagnosis of COVID-19

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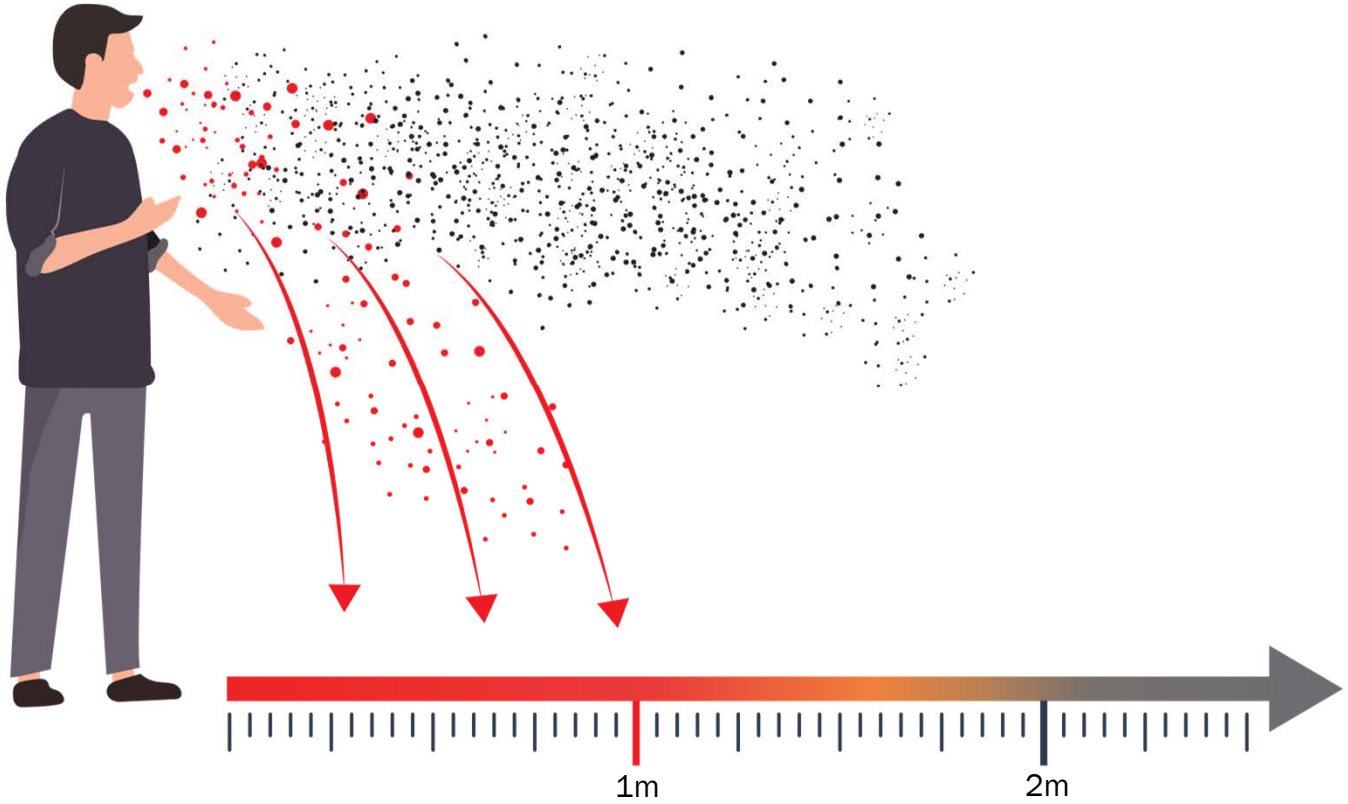
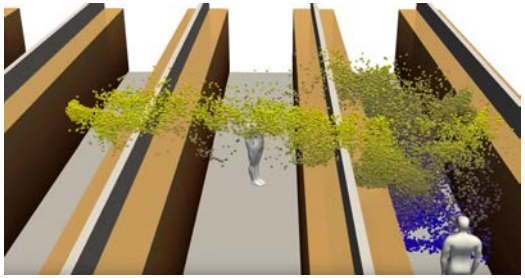
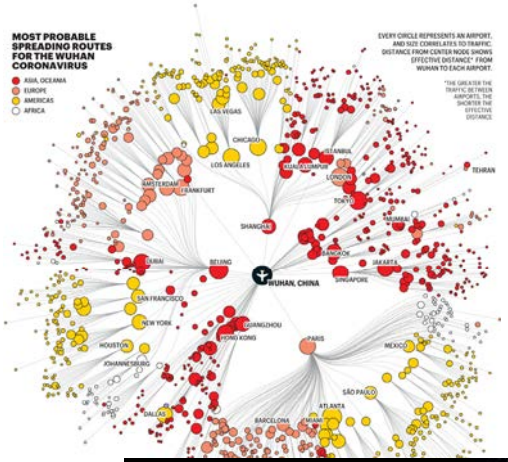
Motivation

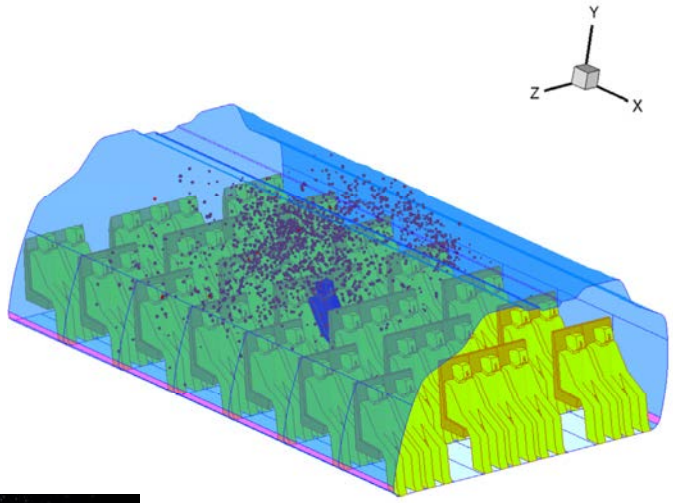


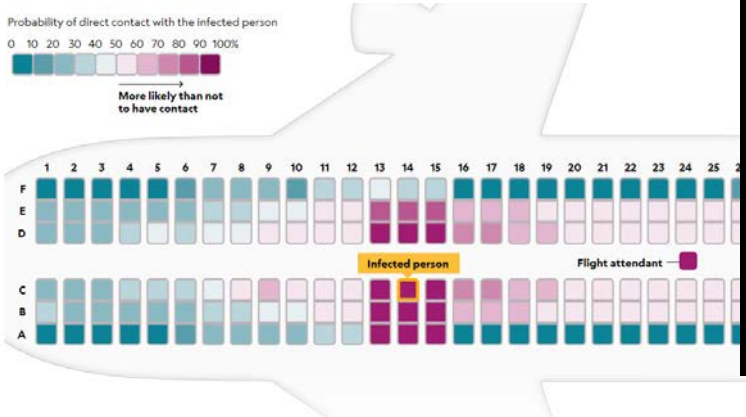
Motivation

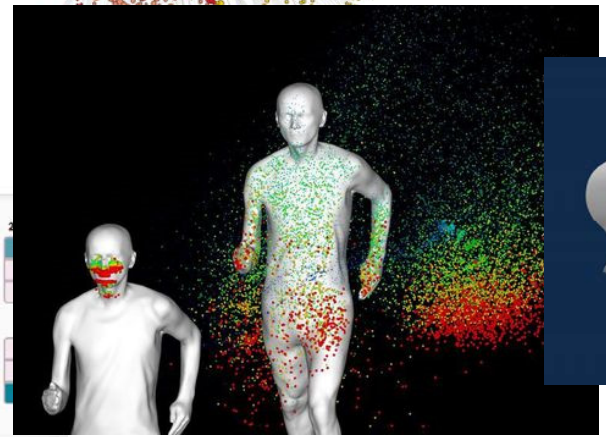
Spreading Virus

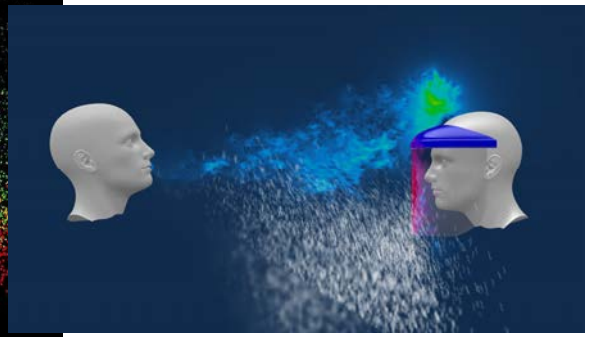




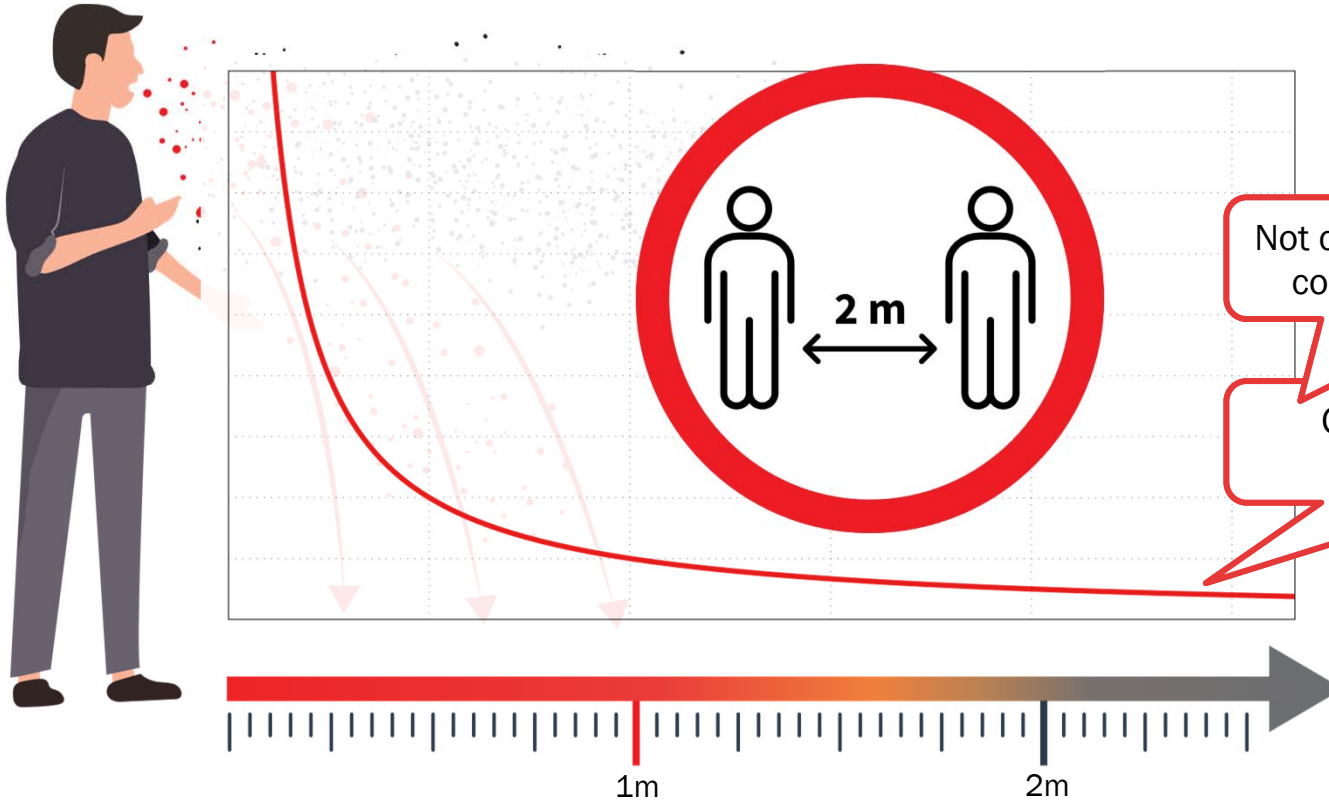








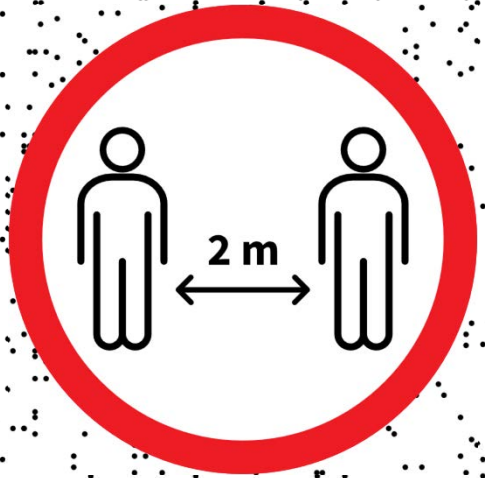
Motivation



Not considering transmission via contaminated surfaces, etc.

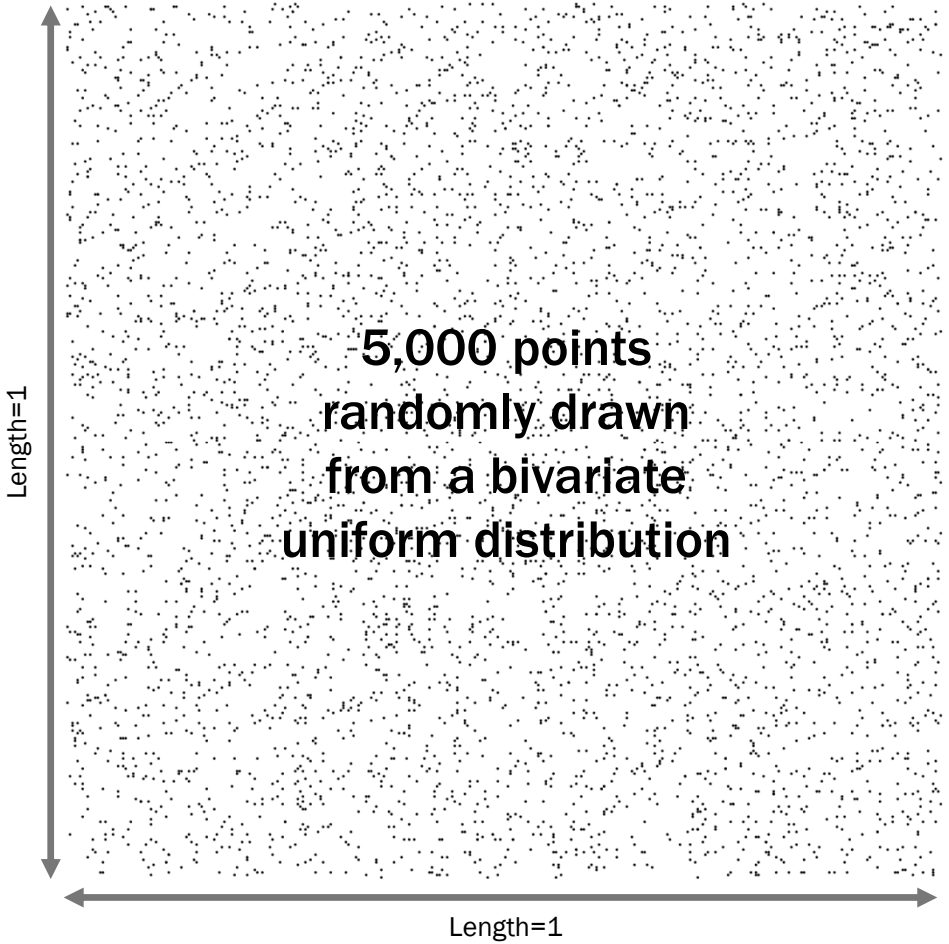
Qualitative transmission "decay curve"

Motivation



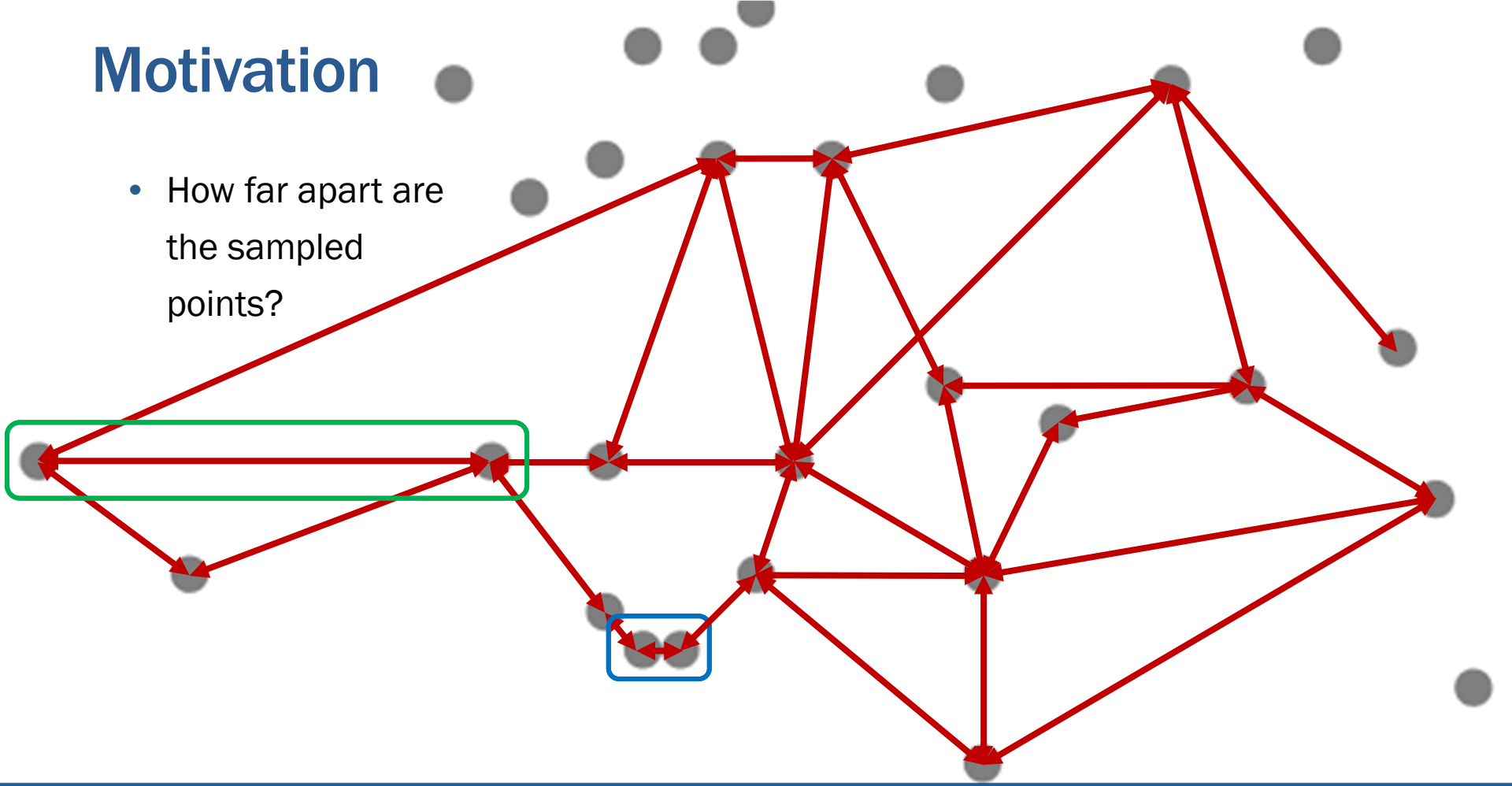
Motivation

- How far apart are uniformly distributed points in a unit square?
- How many are in “spitting distance”?



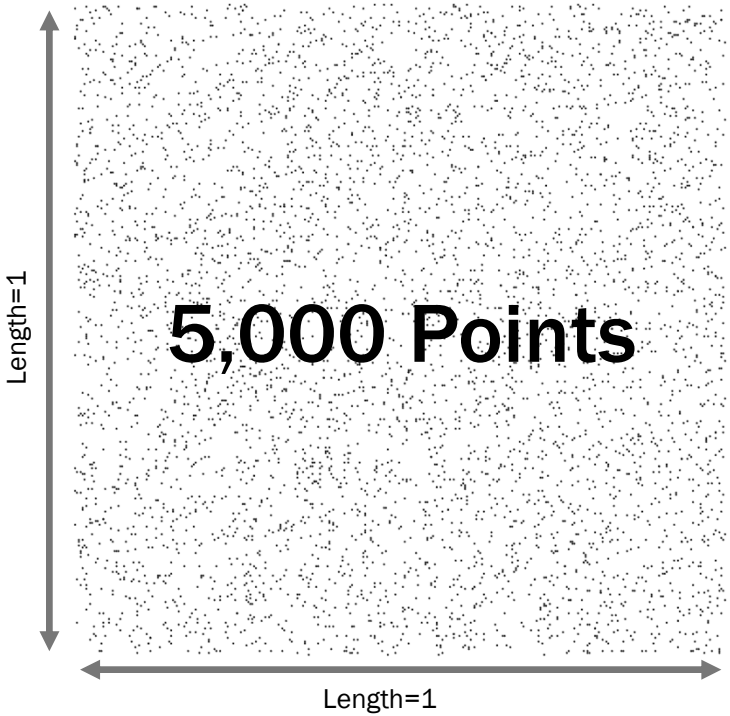
Motivation

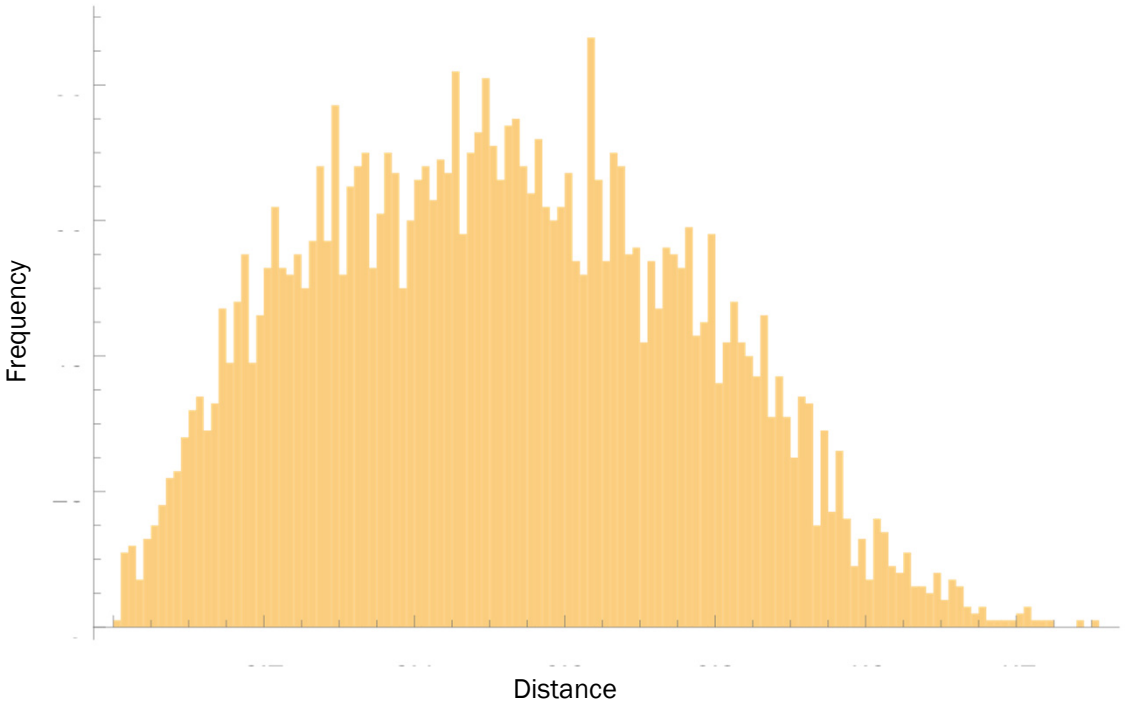
- How far apart are the sampled points?



Motivation

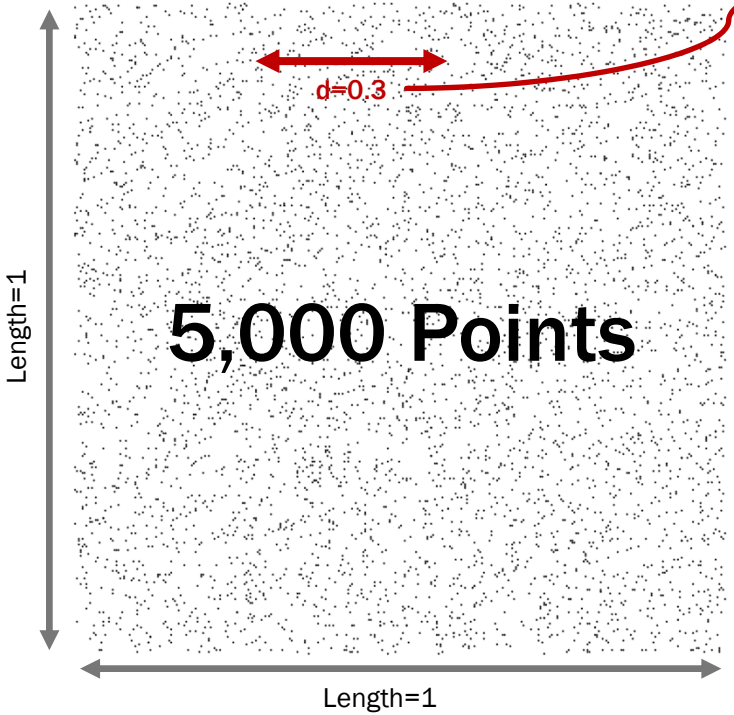
How far apart are these points?



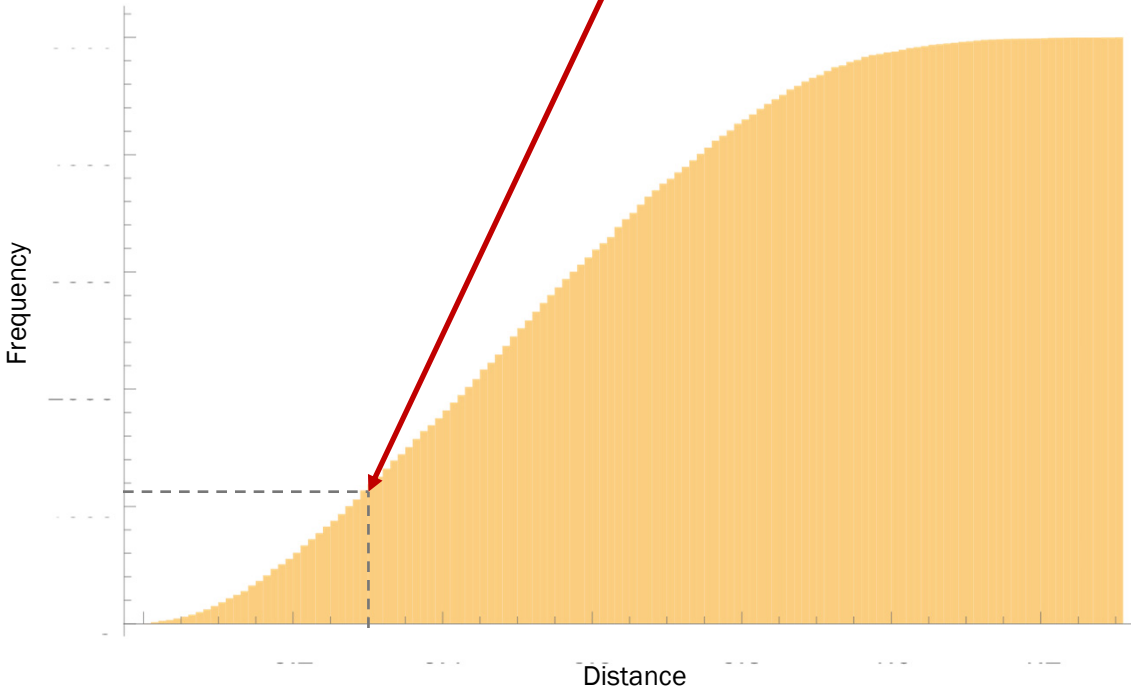


Motivation

How far apart are these points?



Between these 5,000 points, approx. 1,200 are less than 0.3 units apart.



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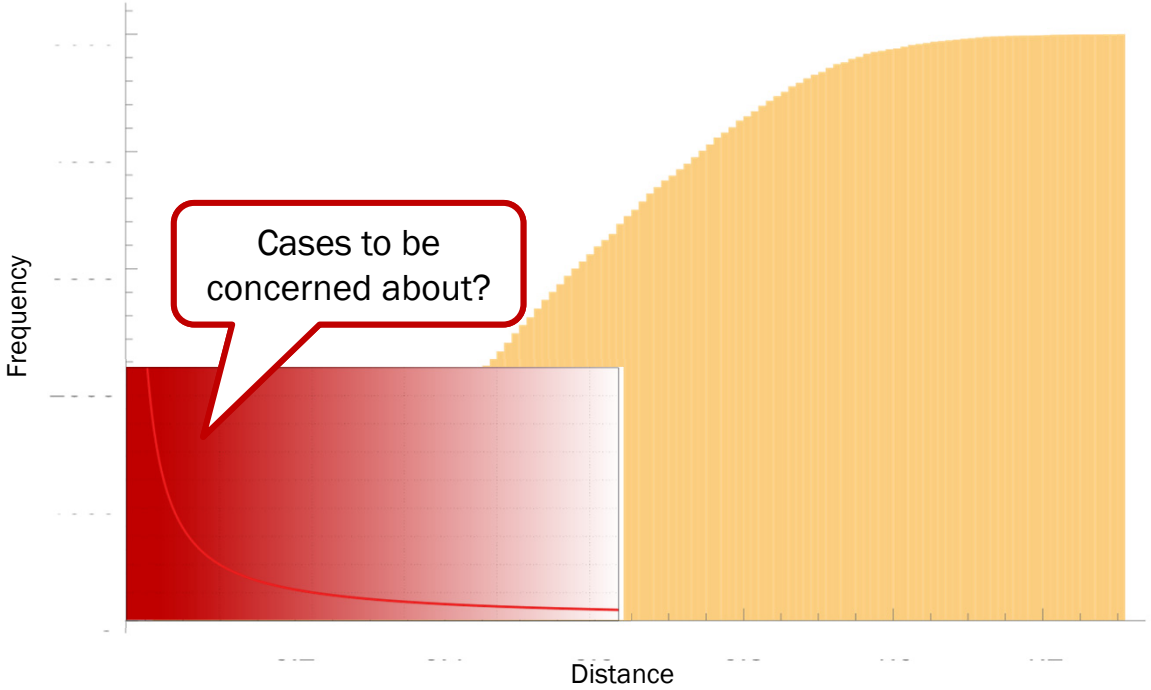
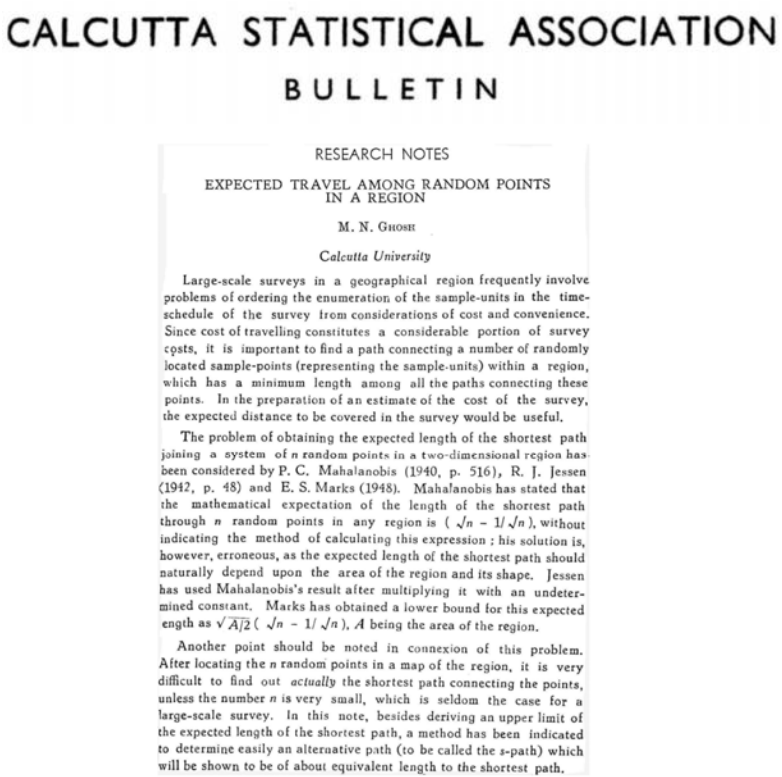
How far apart are these points?



Motivation



CALCUTTA STATISTICAL ASSOCIATION

BULLETIN

RESEARCH NOTES

EXPECTED TRAVEL AMONG RANDOM POINTS IN A REGION

M. N. GHOSH

Calcutta University

Large-scale surveys in a geographical region frequently involve problems of ordering the enumeration of the sample-units in the time-schedule of the survey from considerations of cost and convenience. Since cost of travelling constitutes a considerable portion of survey costs, it is important to find a path connecting a number of randomly located sample-points (representing the sample-units) within a region, which has a minimum length among all the paths connecting these points. In the preparation of an estimate of the cost of the survey, the expected distance to be covered in the survey would be useful.

The problem of obtaining the expected length of the shortest path joining a system of n random points in a two-dimensional region has been considered by P. C. Mahalanobis (1940, p. 516), R. J. Jessen (1942, p. 48) and E. S. Marks (1948). Mahalanobis has stated that the mathematical expectation of the length of the shortest path through n random points in any region is $(\sqrt{n} - 1/\sqrt{n})$, without indicating the method of calculating this expression; his solution is, however, erroneous, as the expected length of the shortest path should naturally depend upon the area of the region and its shape. Jessen has used Mahalanobis's result after multiplying it with an undetermined constant. Marks has obtained a lower bound for this expected length as $\sqrt{A/2}\,(\sqrt{n} - 1/\sqrt{n})$, A being the area of the region.

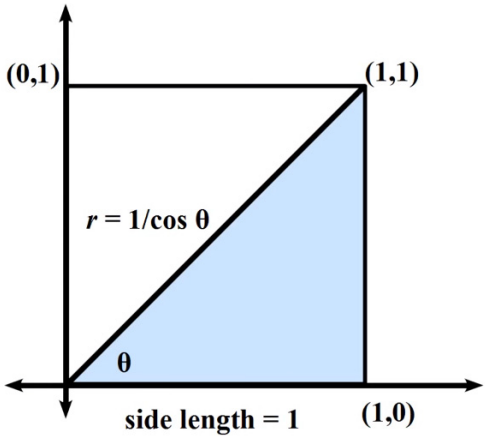
Another point should be noted in connexion of this problem. After locating the n random points in a map of the region, it is very difficult to find out *actually* the shortest path connecting the points, unless the number n is very small, which is seldom the case for a large-scale survey. In this note, besides deriving an upper limit of the expected length of the shortest path, a method has been indicated to determine easily an alternative path (to be called the s-path) which will be shown to be of about equivalent length to the shortest path.

- B. Ghosh, “On the distribution of random distances in a rectangle,” Science and Culture, vol. 8 (9), p. 388, 1943.
- B. Ghosh, “On random distance between two rectangles,” Science and Culture, vol. 8 (11), p. 464, 1943. [3]
- B. Ghosh, “Random distance within a rectangle and between two rectangles,” Bulletin of the Calcutta Mathematical Society, vol. 43, pp. 17-24, 1951.
- Ghosh, M. N. “Expected Travel Among Random Points in a Region.” Calcutta Statistical Association Bulletin 2.2 (1949): 83-87.

Motivation

Video on Computing the Mean Distance

Method 2: Exact answer with integrals



Substitute

$$4\int_0^{\pi/4} 2\int_0^{1/\cos\theta} f(r,\theta)\,r\,dr\,d\theta$$

$$8\int_0^{\pi/4}\int_0^{1/\cos\theta} \sqrt{r^2\cos^2\theta+r^2\sin^2\theta}\,(1-r\cos\theta)(1-r\sin\theta)\,r\,dr\,d\theta$$

$$8\int_0^{\pi/4}\int_0^{1/\cos\theta} r(1-r\cos\theta)(1-r\sin\theta)\,r\,dr\,d\theta$$

$$8\int_0^{\pi/4}\int_0^{1/\cos\theta} r^2-r^3\cos\theta-r^3\sin\theta+r^4\cos\theta\sin\theta\,dr\,d\theta$$

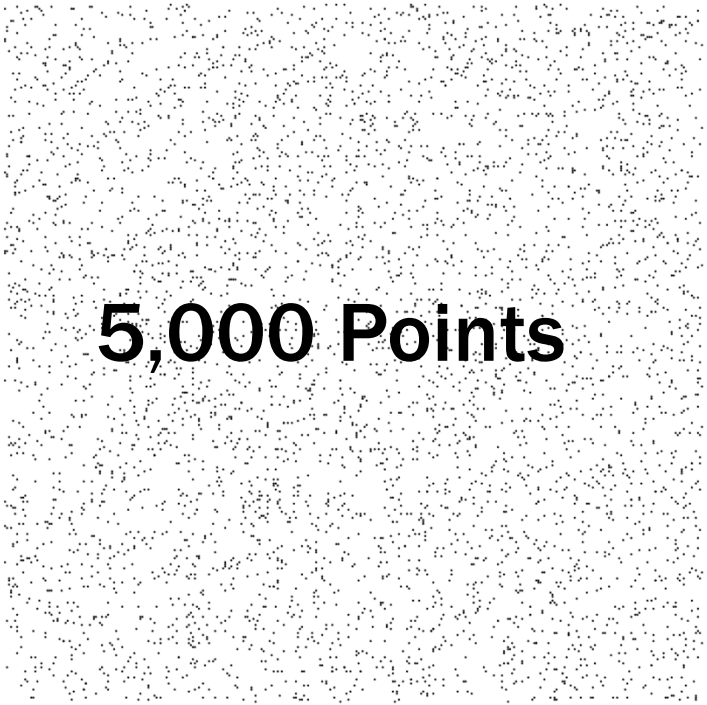
$$8\int_0^{\pi/4} \frac{sec^3\theta}{12}-\frac{sec^3\theta\tan\theta}{20}\,d\theta$$

Mind Your Decisions

https://youtu.be/i4VqXRRXi68

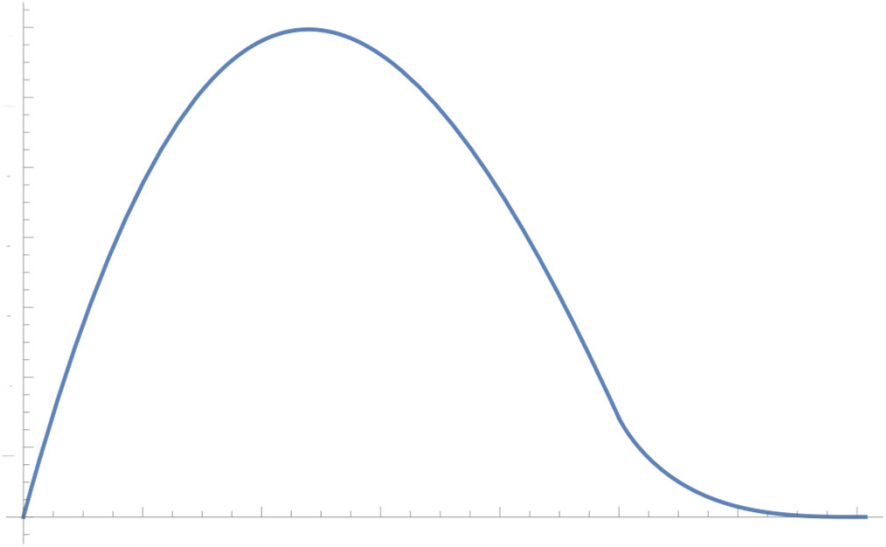
Motivation

How far apart are these points?



Analytical Solution

$$P(l)=\begin{cases} 2l\left(l^2-4l+\pi\right) & 0\le l\le 1 \\ 2l\left(-l^2-4\tan^{-1}\left(\sqrt{l^2-1}\right)+4\sqrt{l^2-1}+\pi-2\right) & 1<l\le\sqrt{2} \end{cases}$$



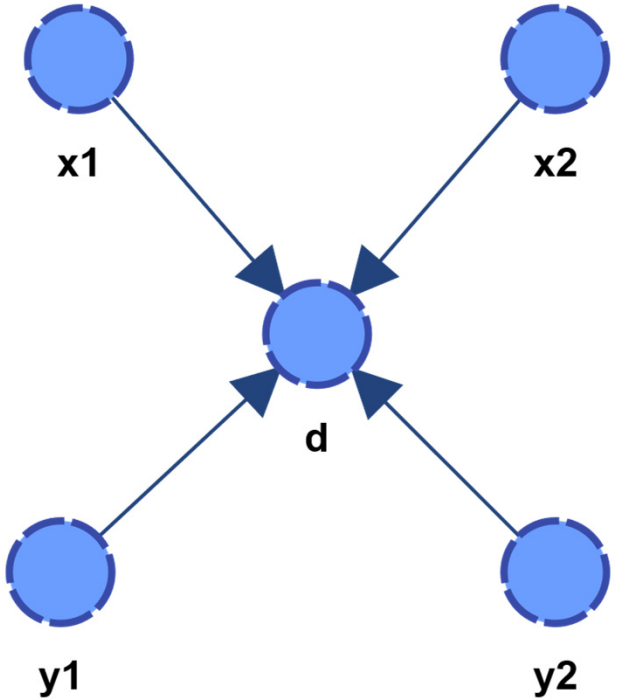
Modeling Objectives

Simple

Practical

Fast

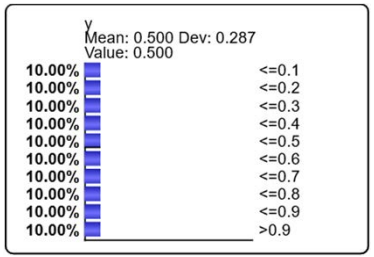
“Reasonable”

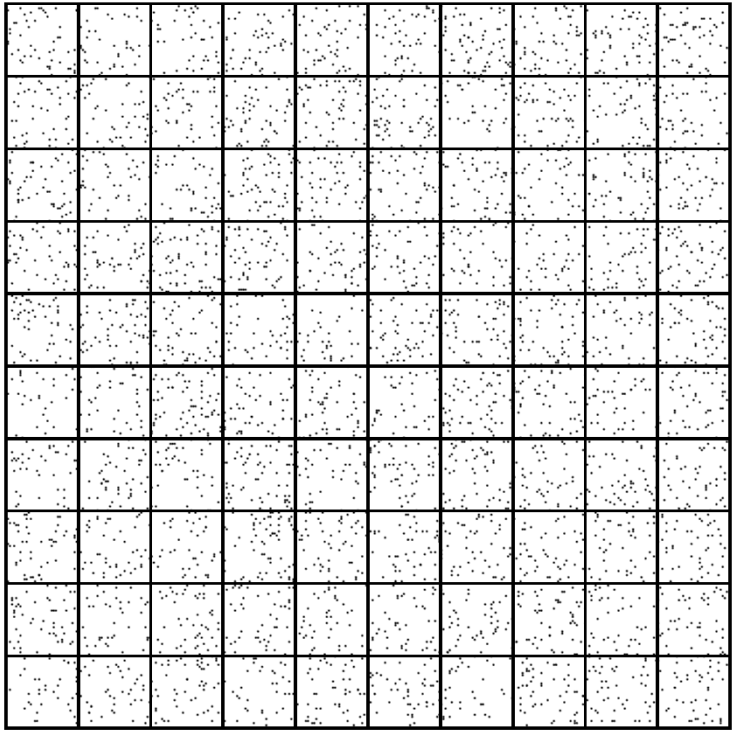


Bayesian Networks

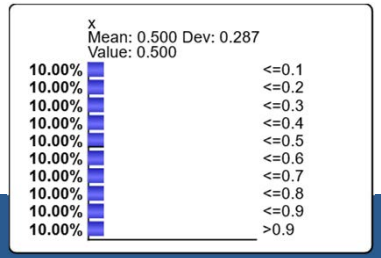
Simplification

- Breaking the unit square into a 10×10 grid.



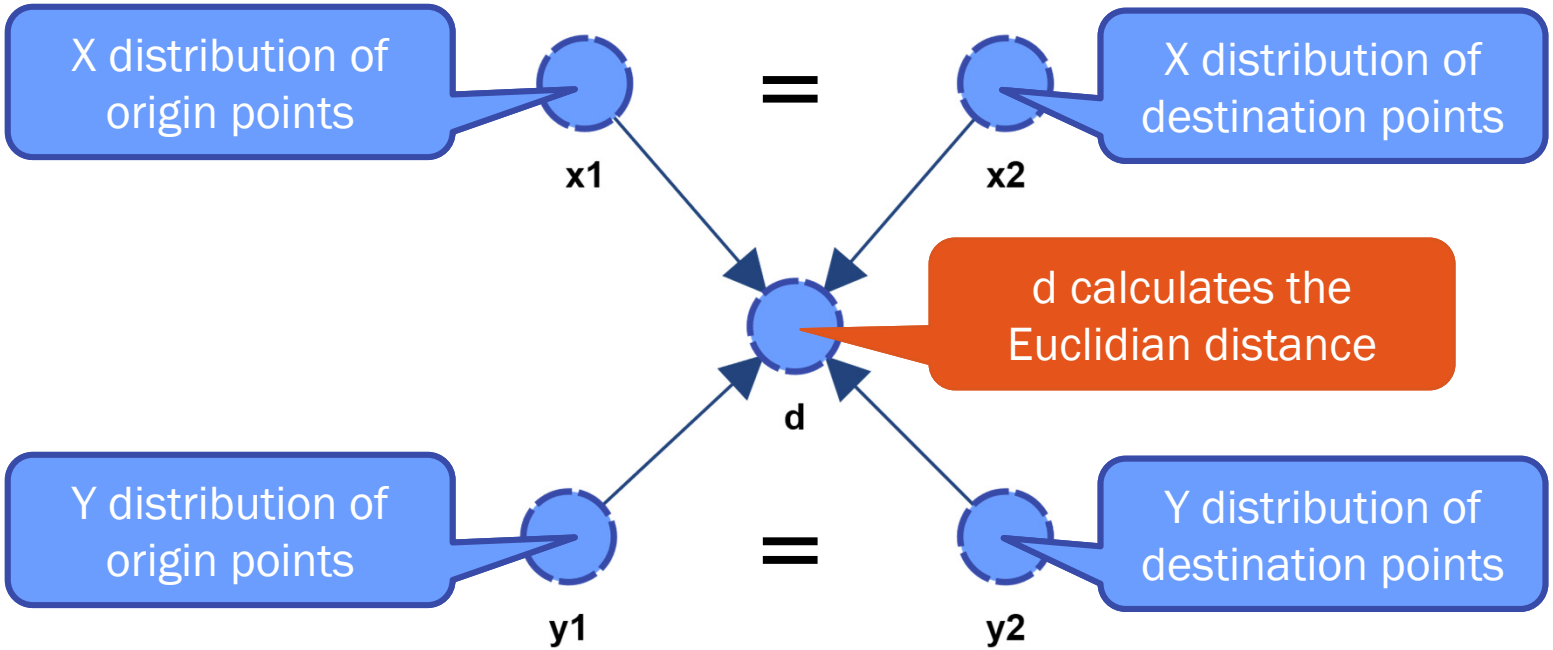


Too coarse for you?



Bayesian Networks to the Rescue

A New Math for Social Distancing



Bayesian Networks to the Rescue

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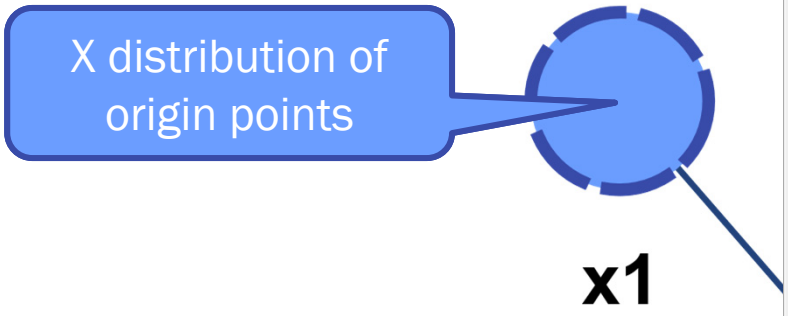

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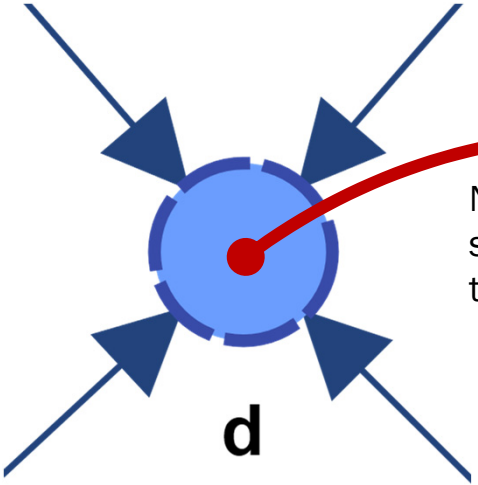
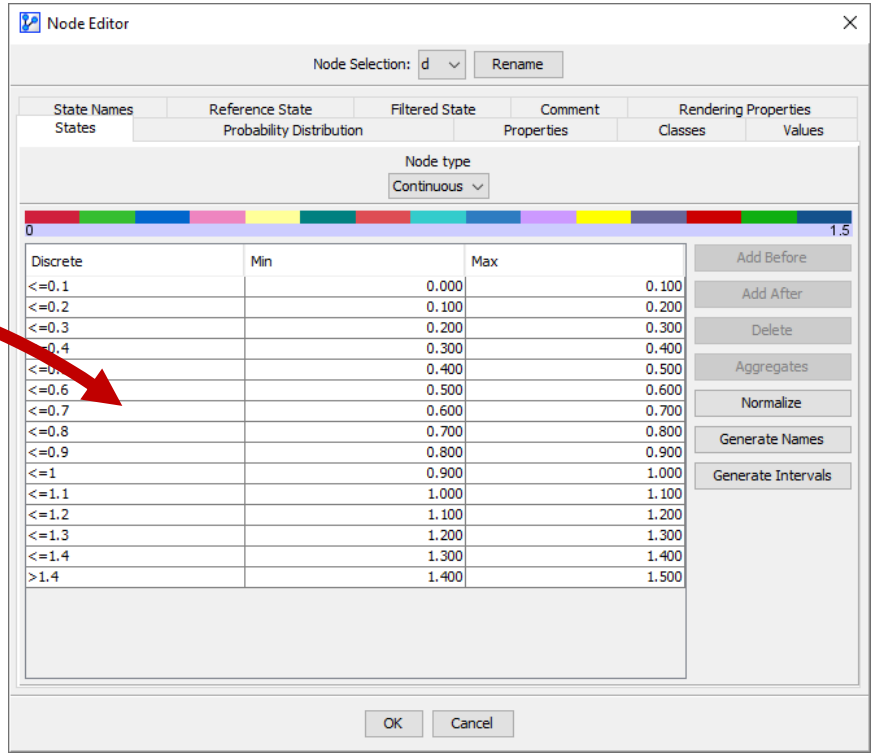


Node d has 15 states to capture the range of 0 to $\sqrt{2}$



Bayesian Networks to the Rescue

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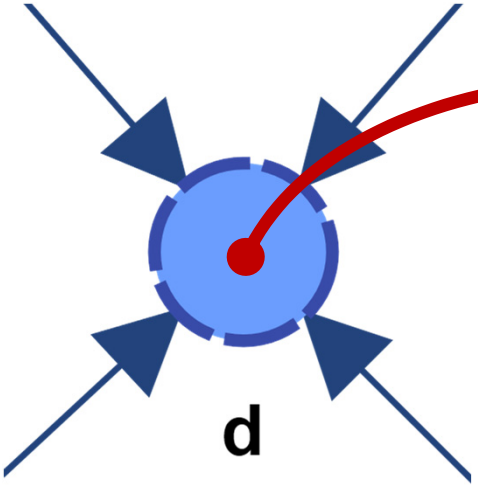
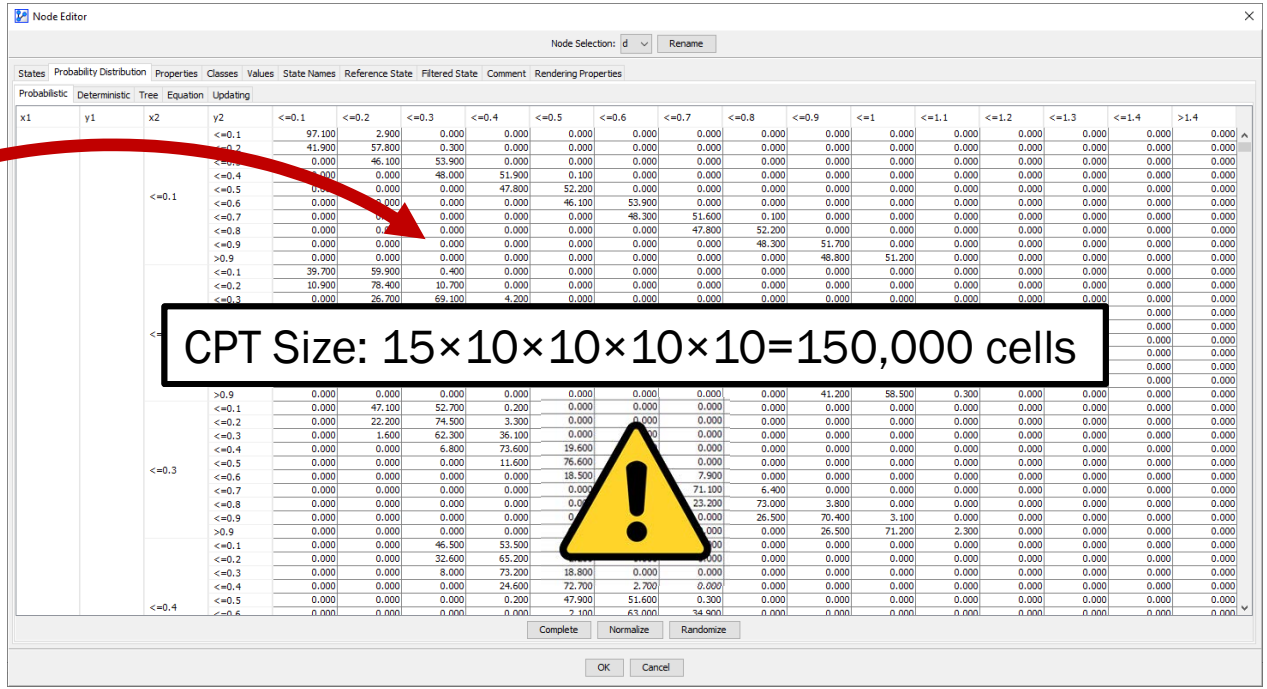
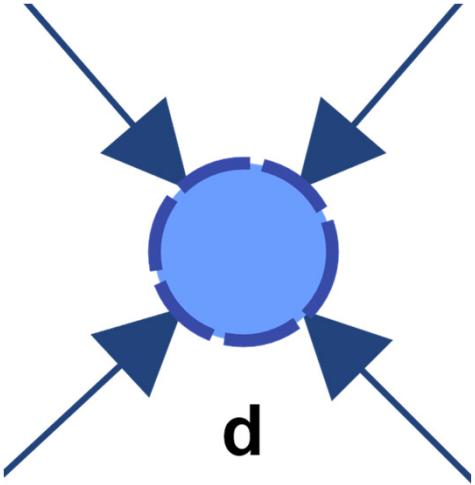




Bayesian Networks to the Rescue

A New Math for Social Distancing



Euclidian Distance

?d? =
SQRT((?x2?-?x1?)^2+(?y2?-?y1?)^2)

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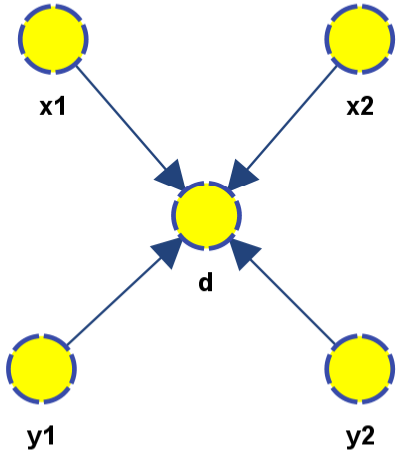
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Total Value: 2.521
Mean Value: 0.504

x1
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

x2
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

d
Mean: 0.521 Dev: 0.250
Value: 0.521

2.88%	<=0.1
7.63%	<=0.2
10.97%	<=0.3
12.99%	<=0.4
13.85%	<=0.5
13.65%	<=0.6
12.49%	<=0.7
10.54%	<=0.8
7.86%	<=0.9
4.62%	<=1
1.76%	<=1.1
0.59%	<=1.2
0.14%	<=1.3
0.01%	<=1.4
0.00%	>1.4

y1
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

y2
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

done!

Distances.x...

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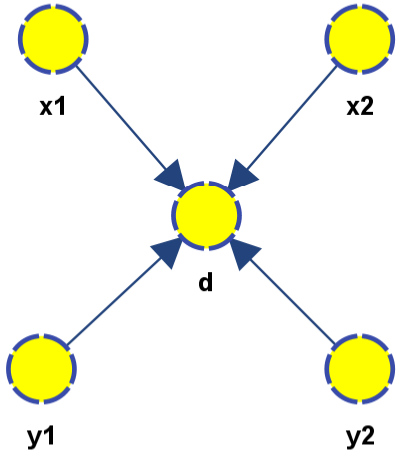
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances.xbl *



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Total Value: 2.521
Mean Value: 0.504

x1
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

x2
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

d
Mean: 0.521 Dev: 0.250
Value: 0.521

2.88%	<=0.1
7.63%	<=0.2
10.97%	<=0.3
12.99%	<=0.4
13.85%	<=0.5
13.65%	<=0.6
12.49%	<=0.7
10.54%	<=0.8
7.86%	<=0.9
4.62%	<=1
1.76%	
0.59%	
0.14%	
0.01%	
0.00%	

y1
Mean: 0.500 Dev: 0.287
Value: 0.500

10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

y2
Mean: 0.500 Dev: 0.287
Value: 0.500

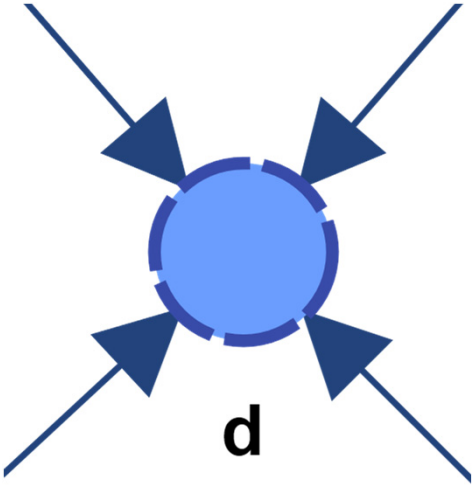
10.00%	<=0.1
10.00%	<=0.2
10.00%	<=0.3
10.00%	<=0.4
10.00%	<=0.5
10.00%	<=0.6
10.00%	<=0.7
10.00%	<=0.8
10.00%	<=0.9
10.00%	>0.9

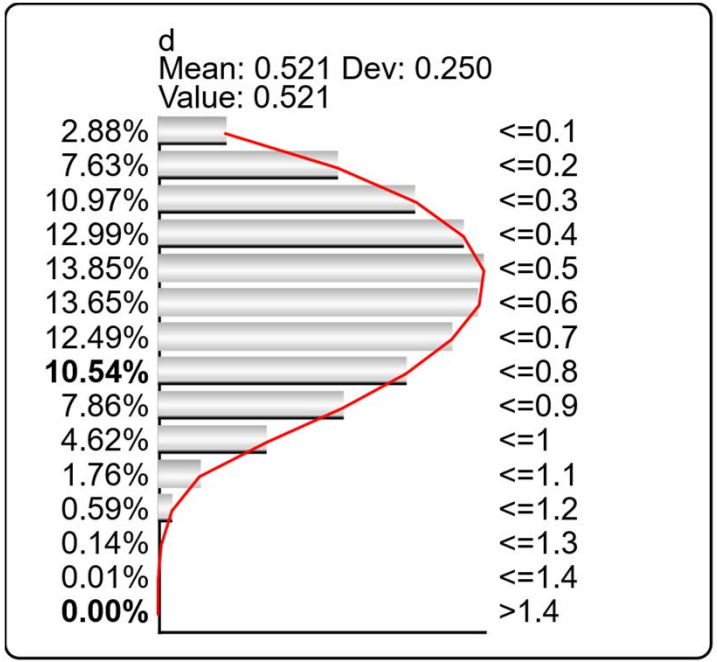
Fix Probabilities
Fix Mean
Hard Evidence
Likelihood Evidence
Probabilistic Evidence
Numerical Evidence
• Observation
Intervention
Absolute Bars
Relative Bars
• Relative Curve
Absolute Variations
Relative Variations
• Show Probabilities
Show Expected Log-Loss
Copy
Delete

Distances.x...

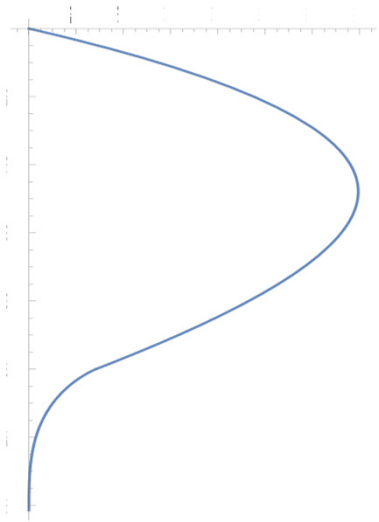
Bayesian Networks to the Rescue

A New Math for Social Distancing



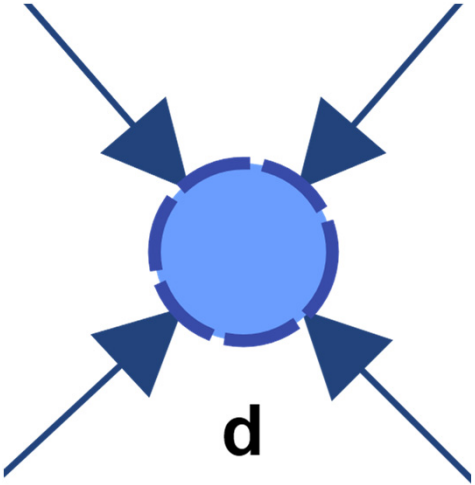


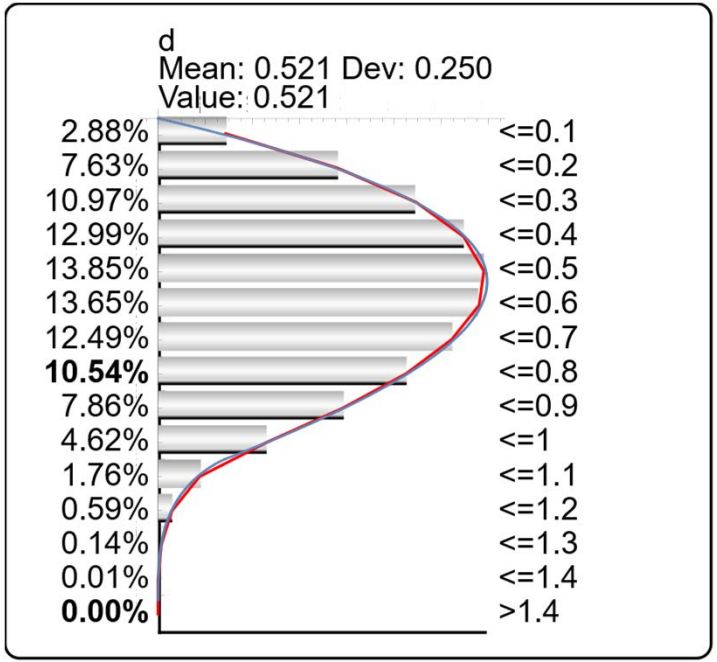
Analytical Solution



Bayesian Networks to the Rescue

A New Math for Social Distancing





The only formula needed:
Euclidian distance

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

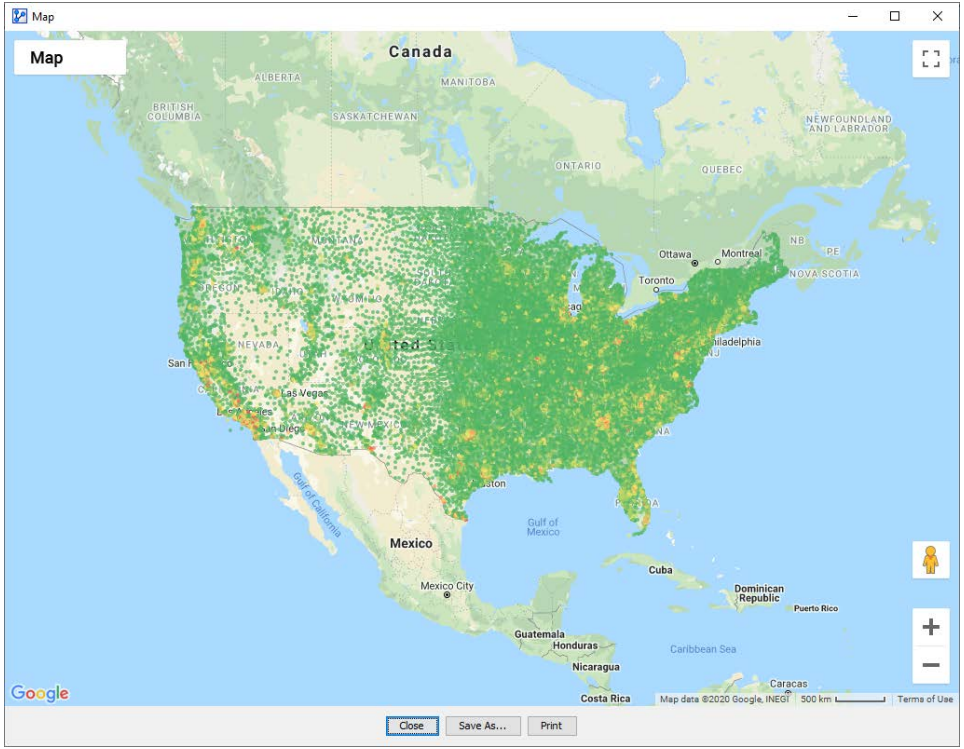
Motivation

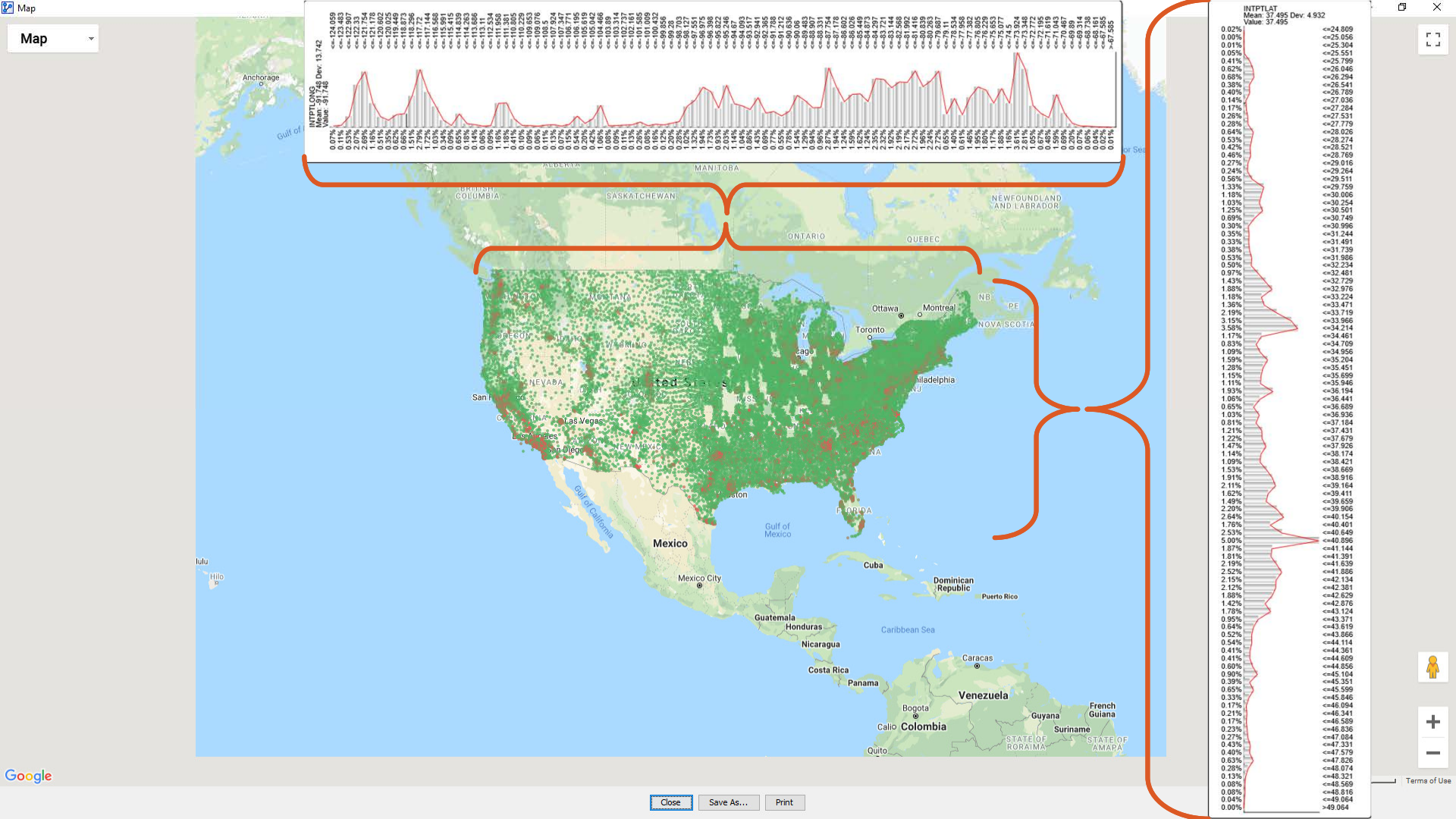
How far apart are these 5,000 points?

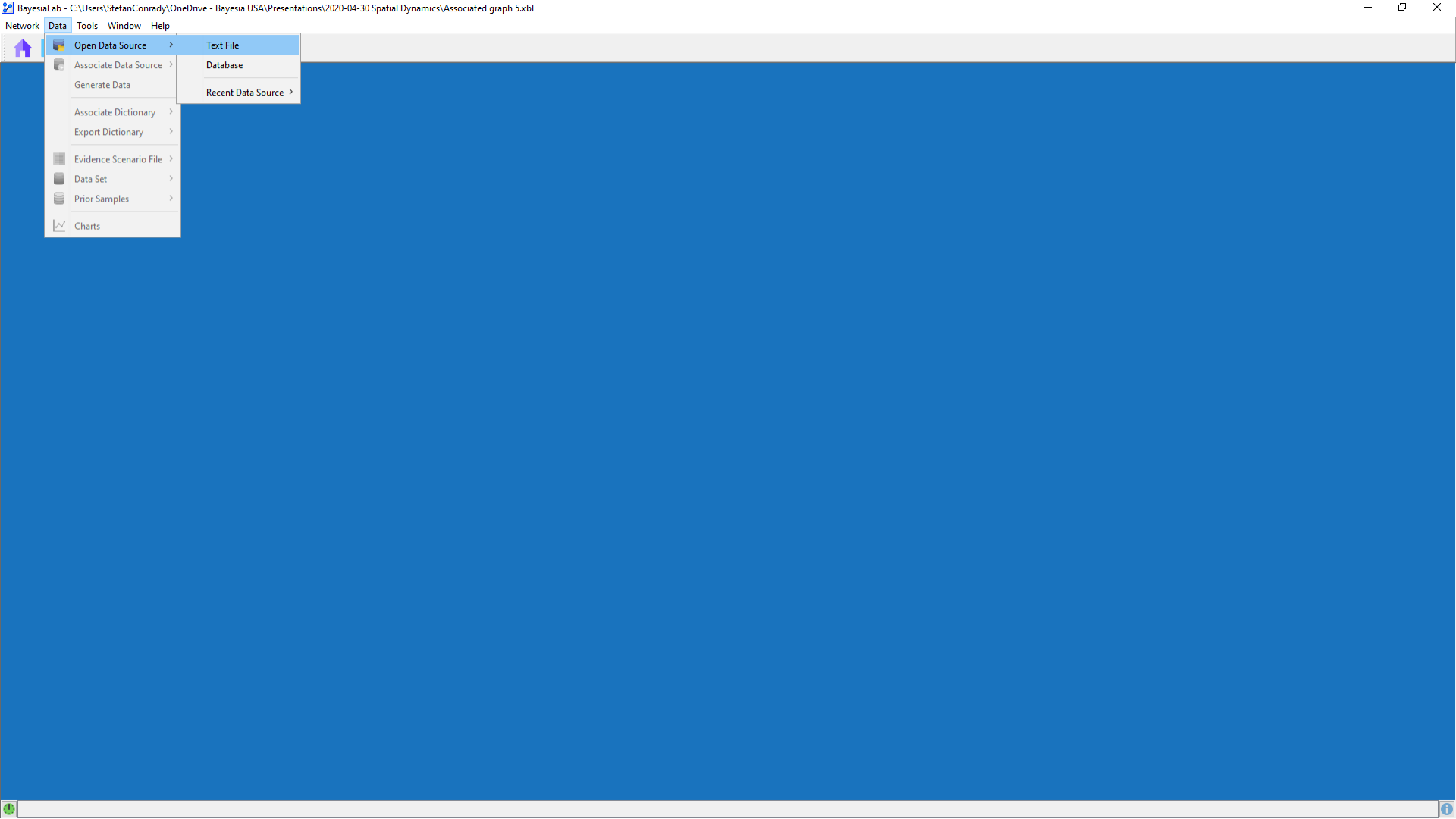
Now what?

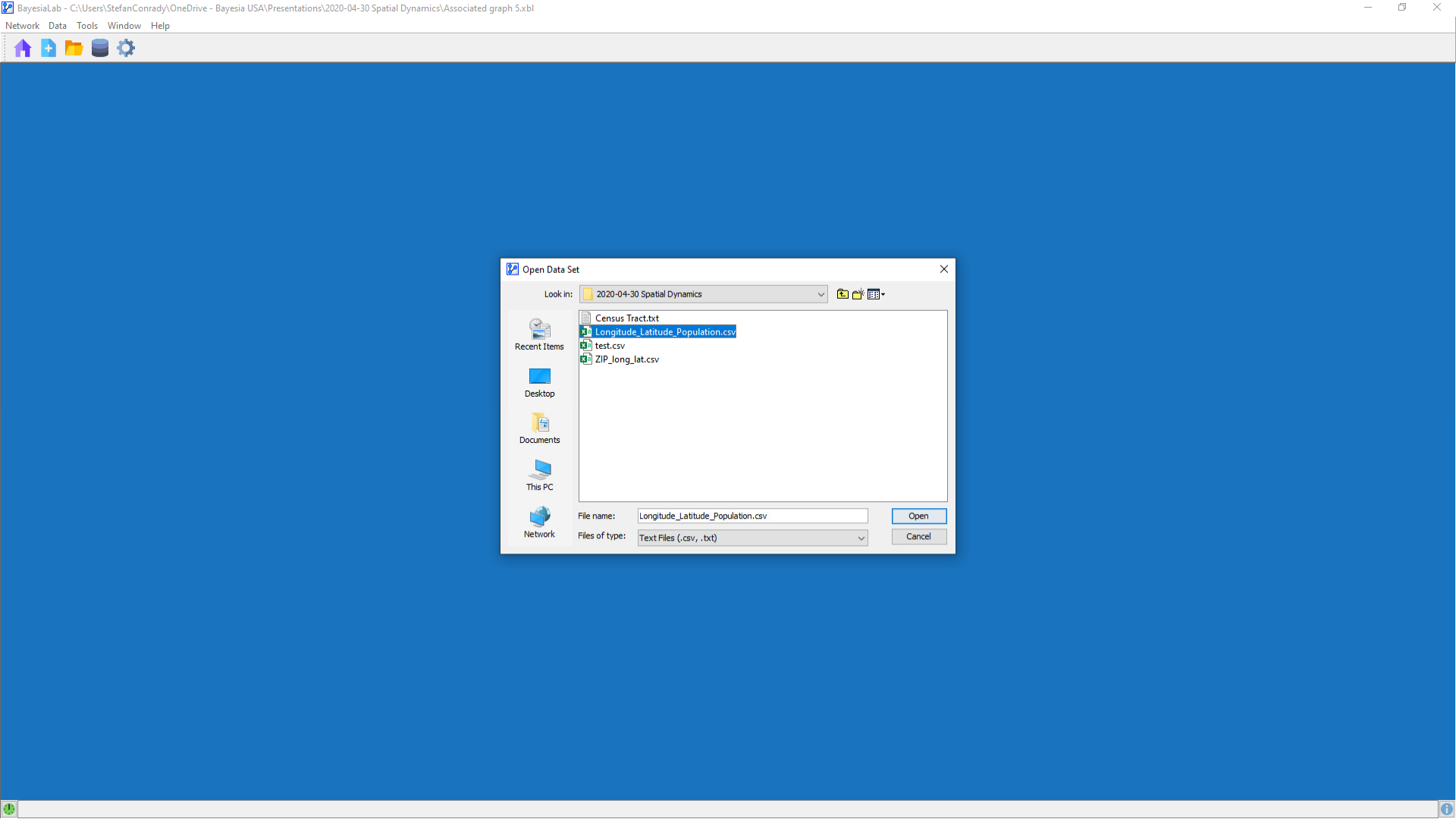
Motivation

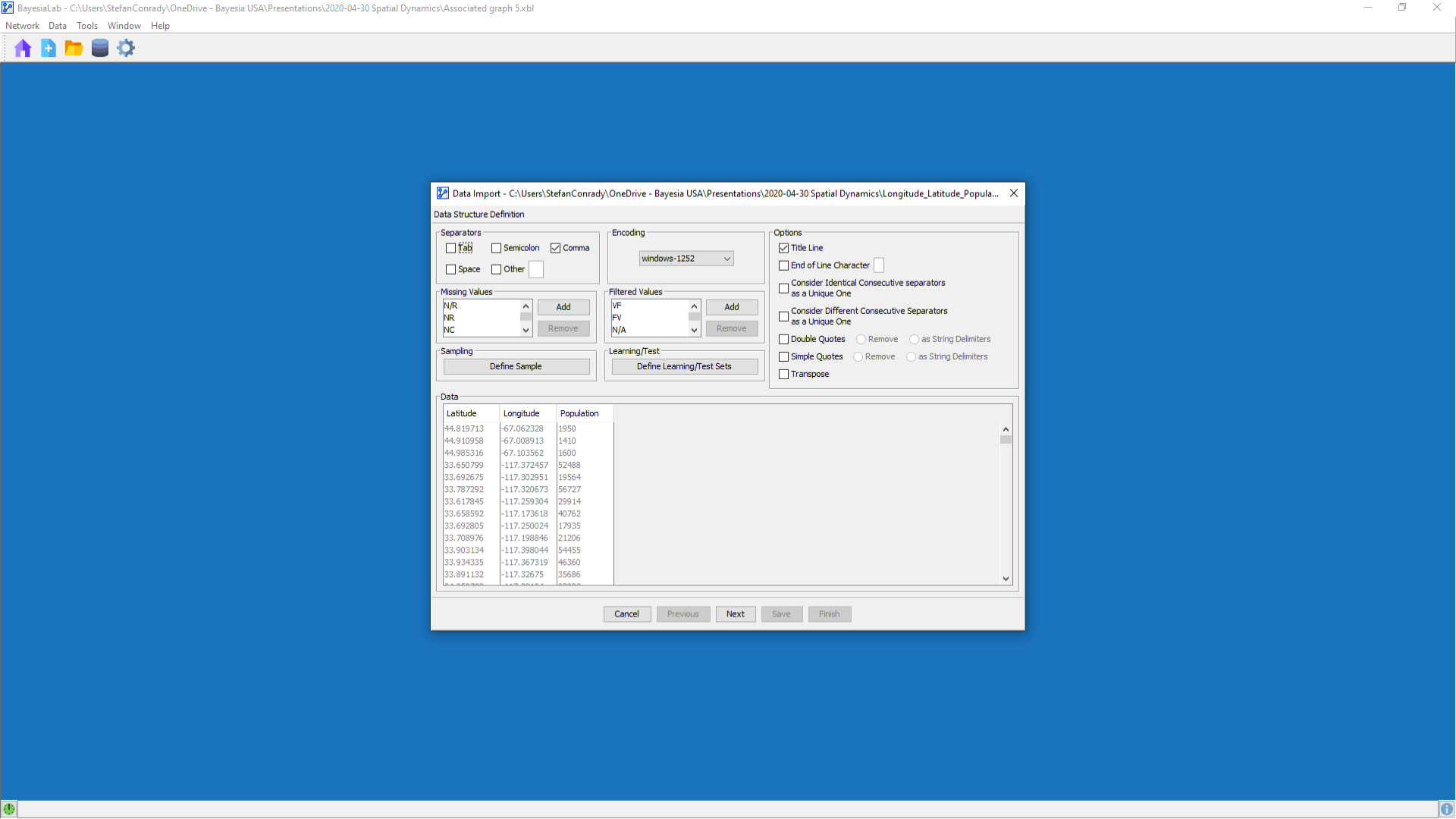
How far apart are these ~~5,000 points?~~ 330 million people




Map
INTPTLONG
Mean: -91.748 Dev: 13.742
Value: -91.748
INTPTLAT
Mean: 37.495 Dev: 4.932
Value: 37.495
Anchorage
Gulf of Alaska
Hilo
Honolulu
ALBERTA
MANITOBA
BRITISH COLUMBIA
SASKATCHEWAN
ONTARIO
QUEBEC
NEWFOUNDLAND AND LABRADOR
NB
PE
NOVA SCOTIA
Ottawa
Montreal
Toronto
Chicago
Philadelphia
NEVADA
San Francisco
Las Vegas
San Diego
NEW MEXICO
Gulf of California
Gulf of Mexico
Mexico
Mexico City
Cuba
Dominican Republic
Puerto Rico
Guatemala
Honduras
Nicaragua
Costa Rica
Panama
Caribbean Sea
Caracas
Venezuela
Bogota
Colombia
Calio
Quito
Guyana
Suriname
French Guiana
STATE OF RORAIMA
STATE OF AMAPA
Google
Terms of Use
Close
Save As...
Print

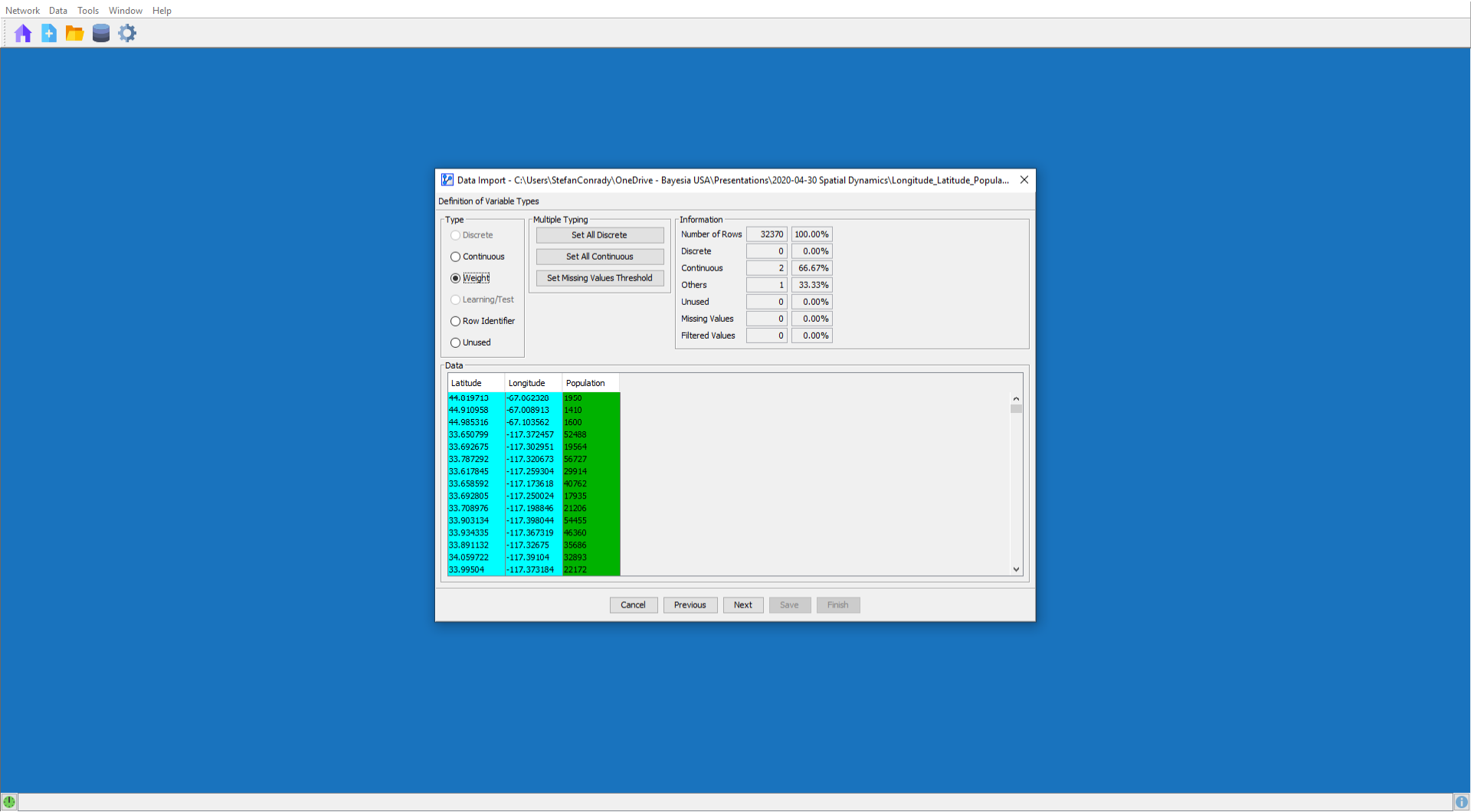

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 5.xbl
Network
Data
Tools
Window
Help
Open Data Source
Associate Data Source
Generate Data
Associate Dictionary
Export Dictionary
Evidence Scenario File
Data Set
Prior Samples
Charts
Text File
Database
Recent Data Source

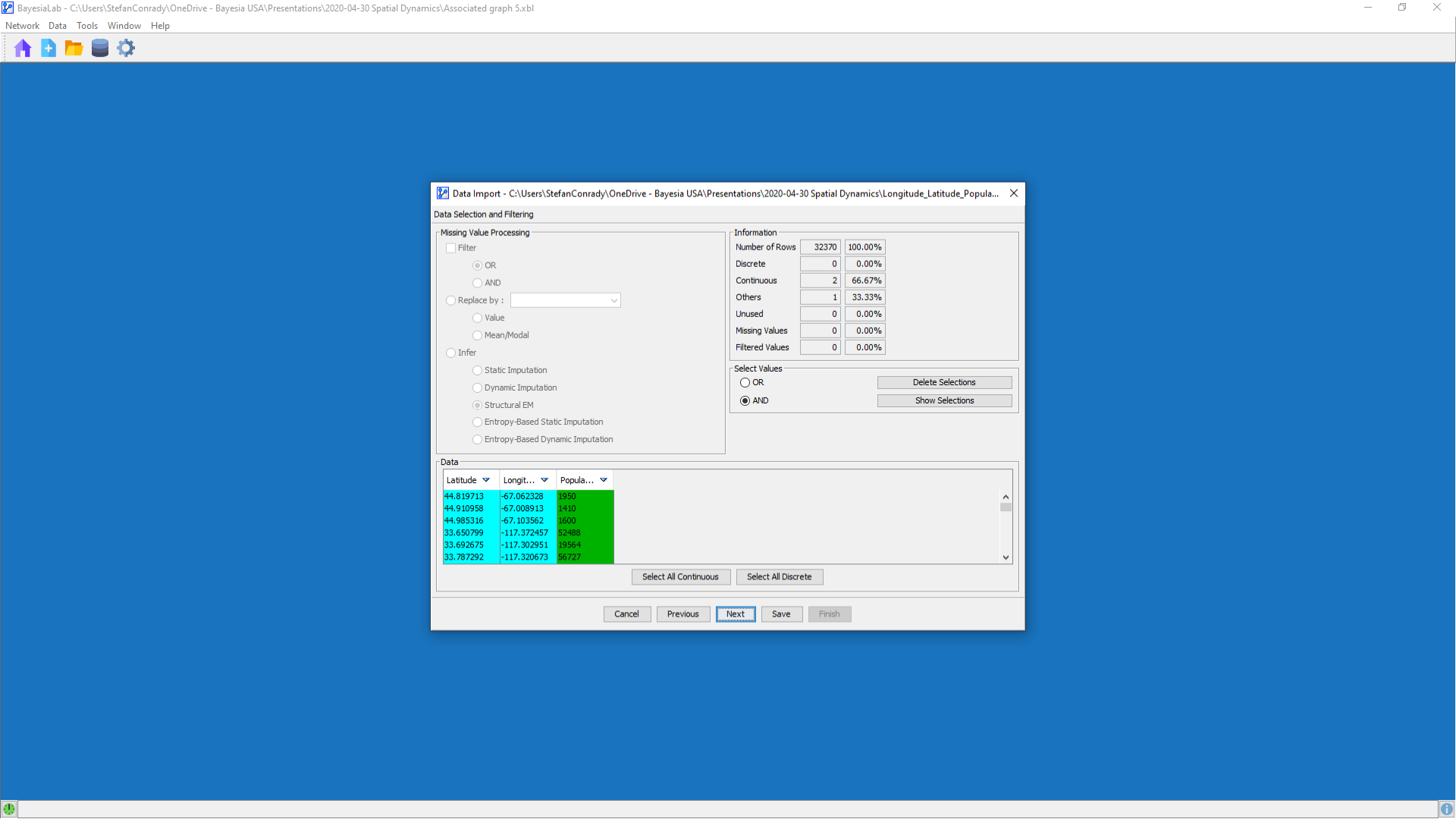

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 5.xbl
Network
Data
Tools
Window
Help
Open Data Set
Look in:
2020-04-30 Spatial Dynamics
Census Tract.txt
Longitude_Latitude_Population.csv
test.csv
ZIP_long_lat.csv
Recent Items
Desktop
Documents
This PC
Network
File name:
Longitude_Latitude_Population.csv
Open
Files of type:
Text Files (.csv, .txt)
Cancel

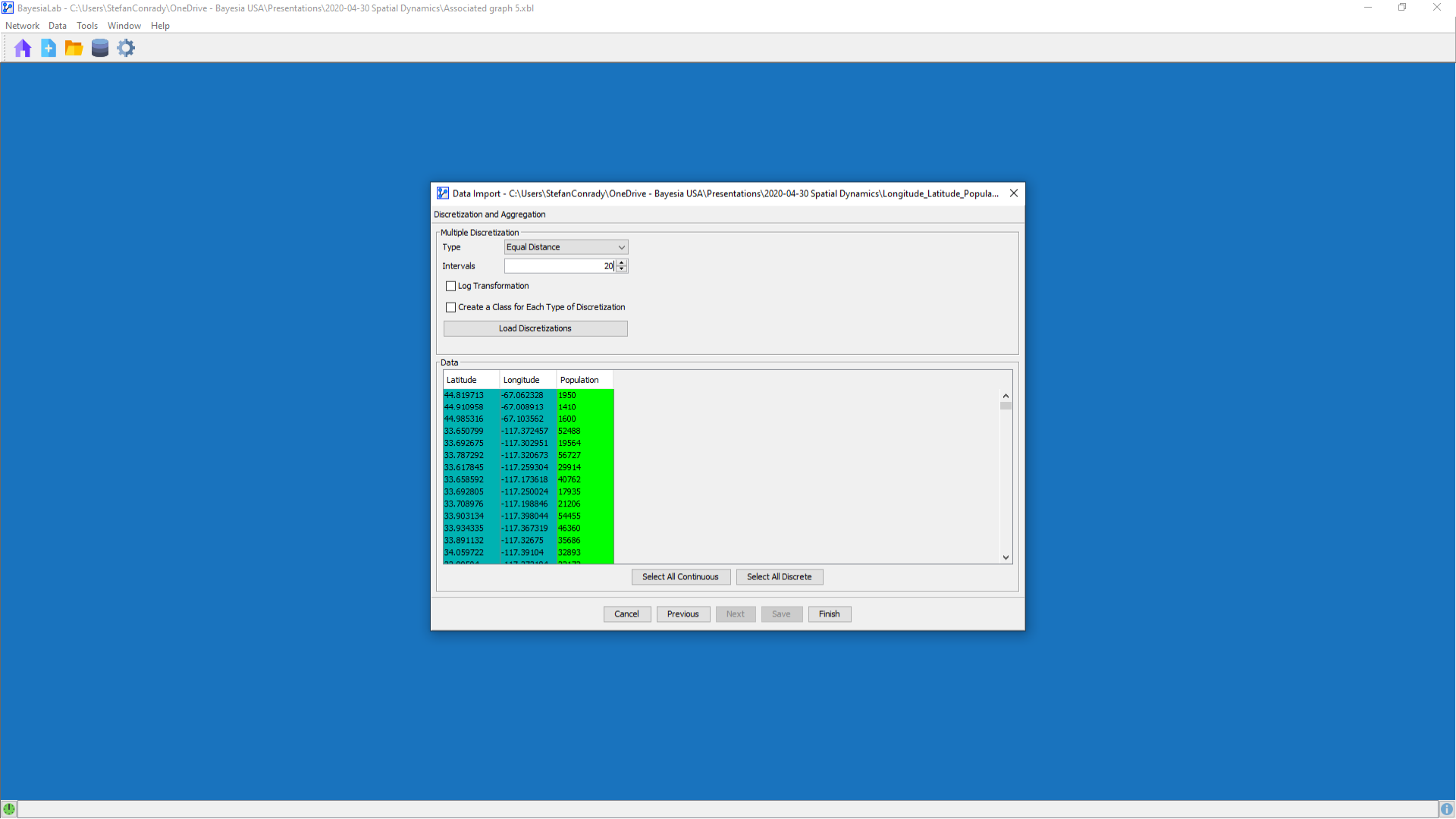

Data Import - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Longitude_Latitude_Popula...
Data Structure Definition
Separators
Tab
Semicolon
Comma
Space
Other
Encoding
windows-1252
Options
Title Line
End of Line Character
Consider Identical Consecutive separators as a Unique One
Consider Different Consecutive Separators as a Unique One
Double Quotes
Remove
as String Delimiters
Simple Quotes
Remove
as String Delimiters
Transpose
Missing Values
N/R
NR
NC
Add
Remove
Filtered Values
VF
FV
N/A
Add
Remove
Sampling
Define Sample
Learning/Test
Define Learning/Test Sets
Data
Latitude Longitude Population
44.819713 -67.062328 1950
44.910958 -67.008913 1410
44.985316 -67.103562 1600
33.650799 -117.372457 52488
33.692675 -117.302951 19564
33.787292 -117.320673 56727
33.617845 -117.259304 29914
33.658592 -117.173618 40762
33.692805 -117.250024 17935
33.708976 -117.198846 21206
33.903134 -117.398044 54455
33.934335 -117.367319 46360
33.891132 -117.32675 35686
Cancel
Previous
Next
Save
Finish

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 5.xbl

Network Data Tools Window Help




BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 5.xbl
Network
Data
Tools
Window
Help
Data Import - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Longitude_Latitude_Popula...
Data Selection and Filtering
Missing Value Processing
Filter
OR
AND
Replace by :
Value
Mean/Modal
Infer
Static Imputation
Dynamic Imputation
Structural EM
Entropy-Based Static Imputation
Entropy-Based Dynamic Imputation
Information
Number of Rows 32370 100.00%
Discrete 0 0.00%
Continuous 2 66.67%
Others 1 33.33%
Unused 0 0.00%
Missing Values 0 0.00%
Filtered Values 0 0.00%
Select Values
OR
AND
Delete Selections
Show Selections
Data
Latitude
Longit...
Popula...
44.819713 -67.062328 1950
44.910958 -67.008913 1410
44.985316 -67.103562 1600
33.650799 -117.372457 52488
33.692675 -117.302951 19564
33.787292 -117.320673 56727
Select All Continuous
Select All Discrete
Cancel
Previous
Next
Save
Finish


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 5.xbl
Network
Data
Tools
Window
Help
Data Import - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Longitude_Latitude_Popula...
Discretization and Aggregation
Multiple Discretization
Type
Equal Distance
Intervals
20
Log Transformation
Create a Class for Each Type of Discretization
Load Discretizations
Data
Latitude
Longitude
Population
44.819713 -67.062328 1950
44.910958 -67.008913 1410
44.985316 -67.103562 1600
33.650799 -117.372457 52488
33.692675 -117.302951 19564
33.787292 -117.320673 56727
33.617845 -117.259304 29914
33.658592 -117.173618 40762
33.692805 -117.250024 17935
33.708976 -117.198846 21206
33.903134 -117.398044 54455
33.934335 -117.367319 46360
33.891132 -117.32675 35686
34.059722 -117.39104 32893
Select All Continuous
Select All Discrete
Cancel
Previous
Next
Save
Finish

BayesiaLab - Associated graph 8.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 8.xbl *

Latitude

Longitude

Joint Probability: 100.00%
Log-Loss: 0
Cases: 32,370
Total Value: -54.253
Mean Value: -27.127

Longitude
Mean: -91.748 Dev: 13.742
Value: -91.748

5.46%	<=-121.754
3.29%	<=-118.873
7.40%	<=-115.991
1.12%	<=-113.11
2.93%	<=-110.229
0.46%	<=-107.347
2.37%	<=-104.466
0.67%	<=-101.585
0.84%	<=-98.703
6.93%	<=-95.822
6.50%	<=-92.941
4.34%	<=-90.06
8.01%	<=-87.178
8.05%	<=-84.297
11.32%	<=-81.416
8.97%	<=-78.534
6.99%	<=-75.653
10.51%	<=-72.772
3.63%	<=-69.89
0.20%	>-69.89

Latitude
Mean: 37.495 Dev: 4.932
Value: 37.495

0.49%	<=25.799
2.21%	<=27.036
1.88%	<=28.274
1.96%	<=29.511
5.48%	<=30.749
1.89%	<=31.986
5.96%	<=33.224
11.46%	<=34.461
5.94%	<=35.699
5.79%	<=36.936
5.85%	<=38.174
8.25%	<=39.411
10.63%	<=40.649
13.38%	<=41.886
9.35%	<=43.124
3.07%	<=44.361
2.95%	<=45.599
1.11%	<=46.836
2.00%	<=48.074
0.33%	>48.074

Associated ...

BayesiaLab - Associated graph 8.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 8.xbl *

y1

x1

Joint Probability: 100.00%
Log-Loss: 0
Cases: 32,370
Total Value: -54.253
Mean Value: -27.127

x1
Mean: -91.748 Dev: 13.742
Value: -91.748

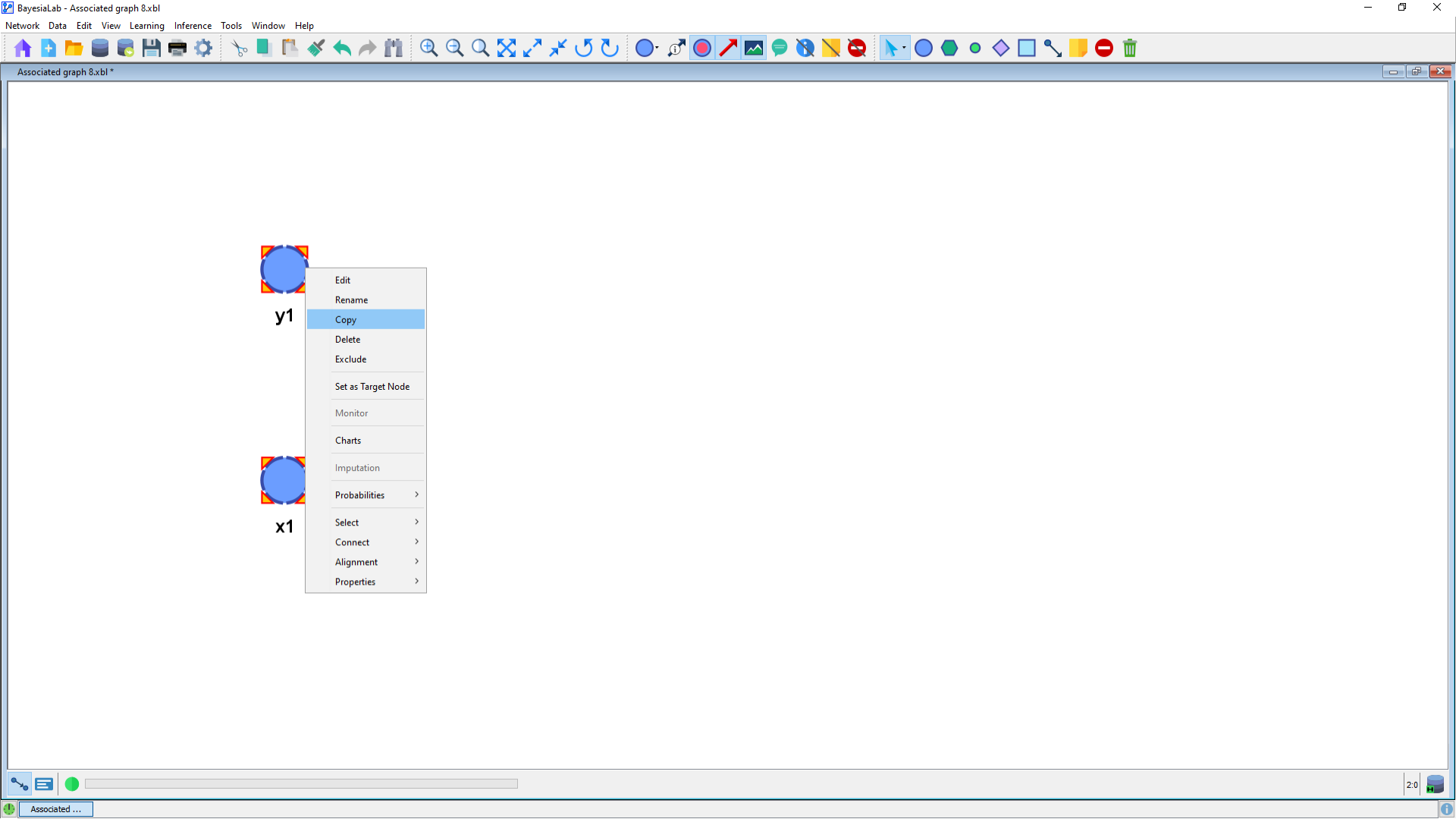
5.46%	<=-121.754
3.29%	<=-118.873
7.40%	<=-115.991
1.12%	<=-113.11
2.93%	<=-110.229
0.46%	<=-107.347
2.37%	<=-104.466
0.67%	<=-101.585
0.84%	<=-98.703
6.93%	<=-95.822
6.50%	<=-92.941
4.34%	<=-90.06
8.01%	<=-87.178
8.05%	<=-84.297
11.32%	<=-81.416
8.97%	<=-78.534
6.99%	<=-75.653
10.51%	<=-72.772
3.63%	<=-69.89
0.20%	>-69.89

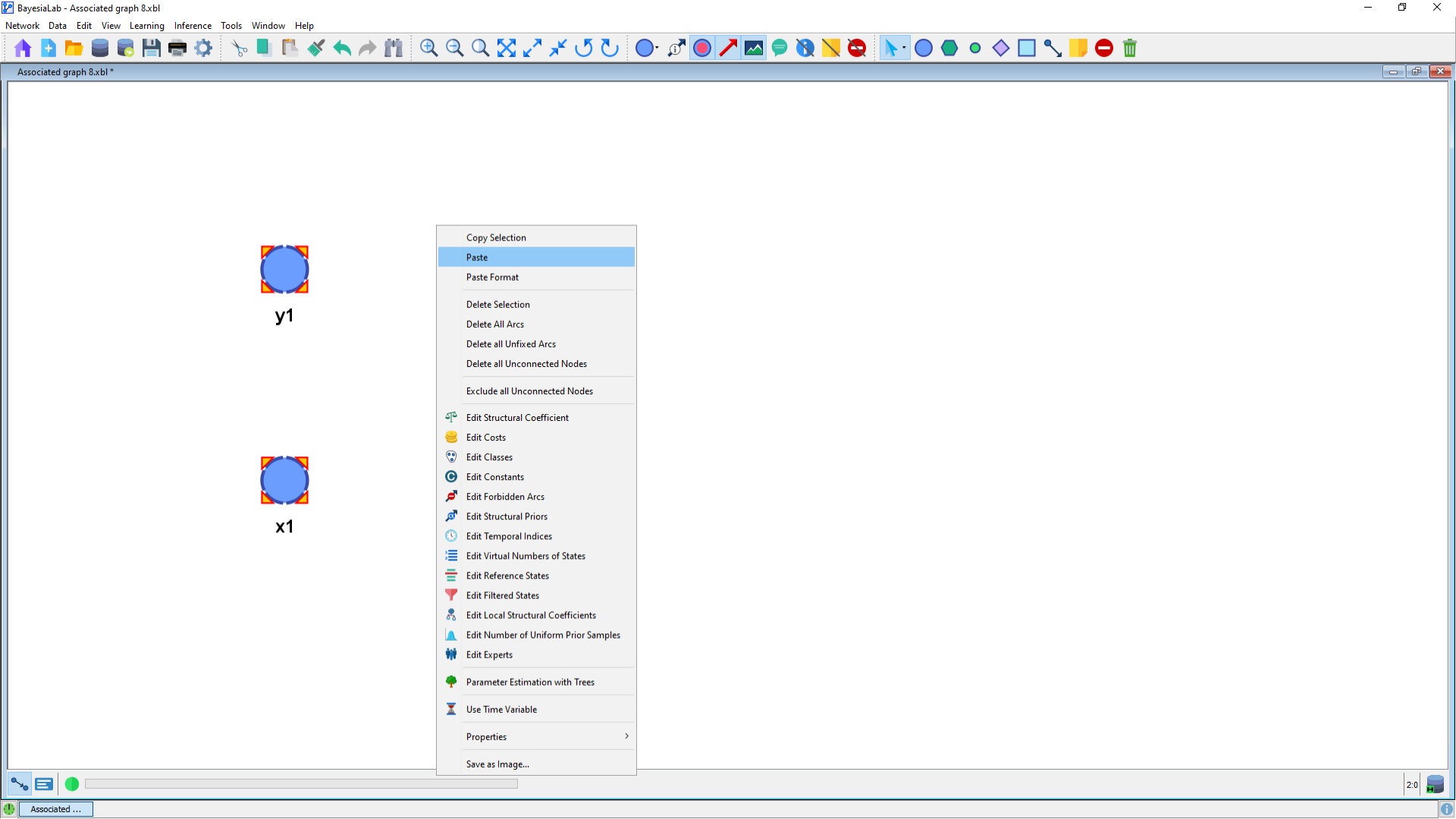
y1
Mean: 37.495 Dev: 4.932
Value: 37.495

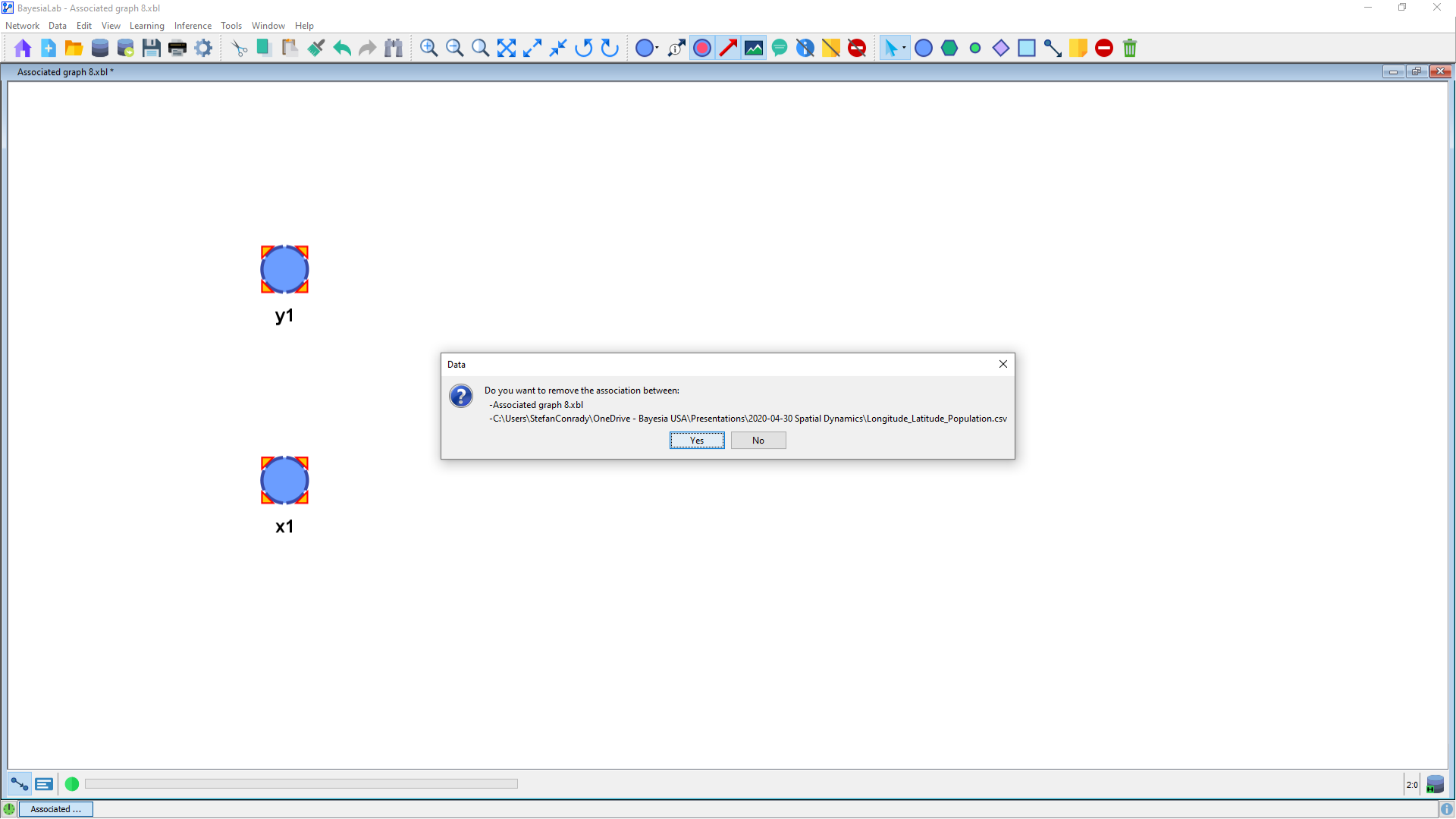
0.49%	<=25.799
2.21%	<=27.036
1.88%	<=28.274
1.96%	<=29.511
5.48%	<=30.749
1.89%	<=31.986
5.96%	<=33.224
11.46%	<=34.461
5.94%	<=35.699
5.79%	<=36.936
5.85%	<=38.174
8.25%	<=39.411
10.63%	<=40.649
13.38%	<=41.886
9.35%	<=43.124
3.07%	<=44.361
2.95%	<=45.599
1.11%	<=46.836
2.00%	<=48.074
0.33%	>48.074

0:0

Associated ...


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
x1
Edit
Rename
Copy
Delete
Exclude
Set as Target Node
Monitor
Charts
Imputation
Probabilities
Select
Connect
Alignment
Properties
Associated ...


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
x1
Copy Selection
Paste
Paste Format
Delete Selection
Delete All Arcs
Delete all Unfixed Arcs
Delete all Unconnected Nodes
Exclude all Unconnected Nodes
Edit Structural Coefficient
Edit Costs
Edit Classes
Edit Constants
Edit Forbidden Arcs
Edit Structural Priors
Edit Temporal Indices
Edit Virtual Numbers of States
Edit Reference States
Edit Filtered States
Edit Local Structural Coefficients
Edit Number of Uniform Prior Samples
Edit Experts
Parameter Estimation with Trees
Use Time Variable
Properties
Save as Image...
2:0
Associated ...


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
x1
Data
Do you want to remove the association between:
-Associated graph 8.xbl
-C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Longitude_Latitude_Population.csv
Yes
No
Associated ...

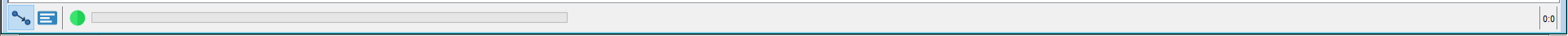
BayesiaLab - Associated graph 8.xbl

Network Data Edit View Learning Inference Tools Window Help

Associated graph 8.xbl *

2:0

Associated ...

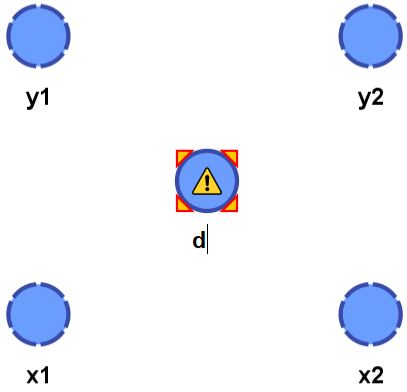


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
y2
N1
x1
x2
0:0
Associated ...

BayesiaLab - Associated graph 8.xbl

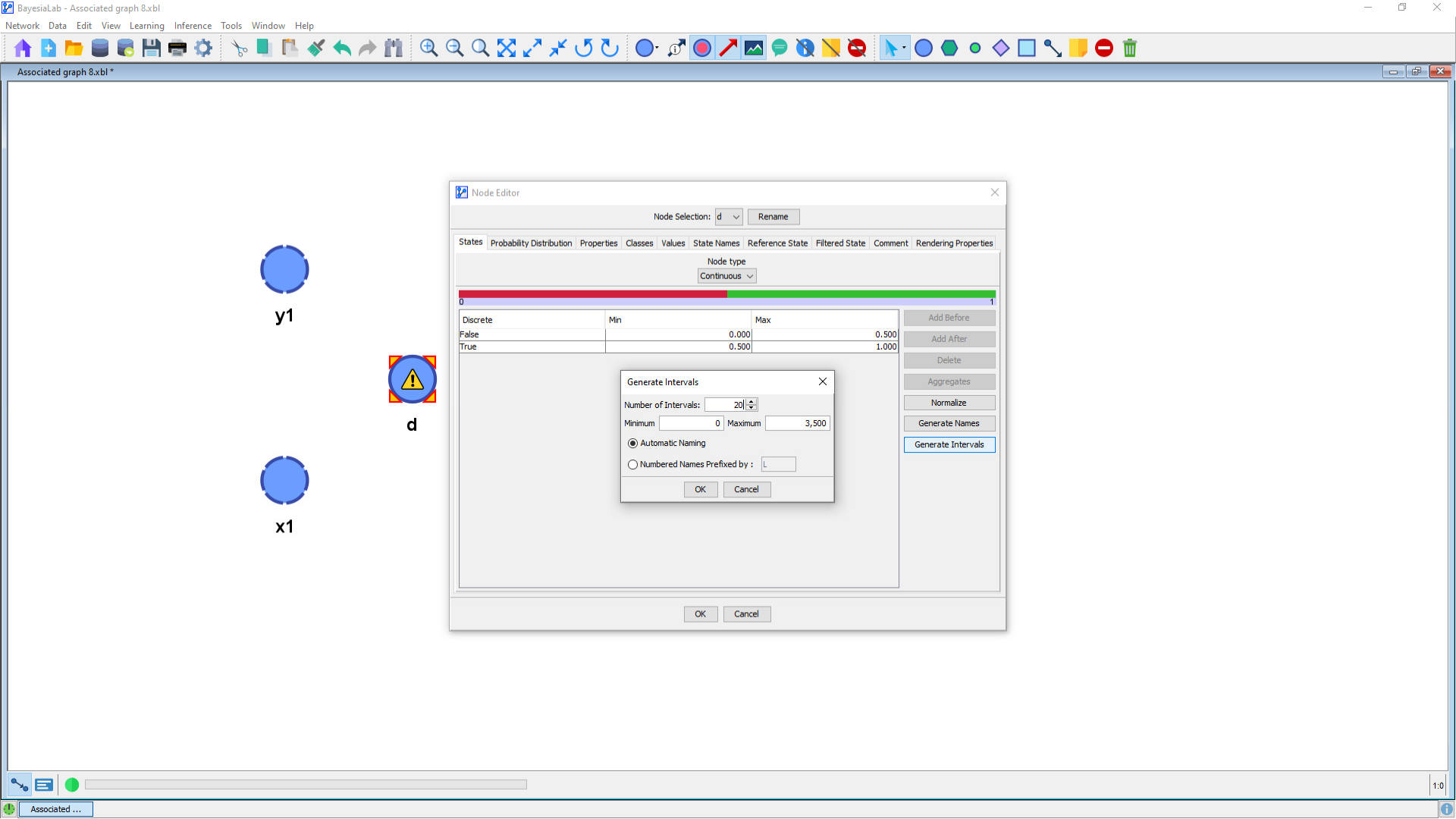
Network Data Edit View Learning Inference Tools Window Help

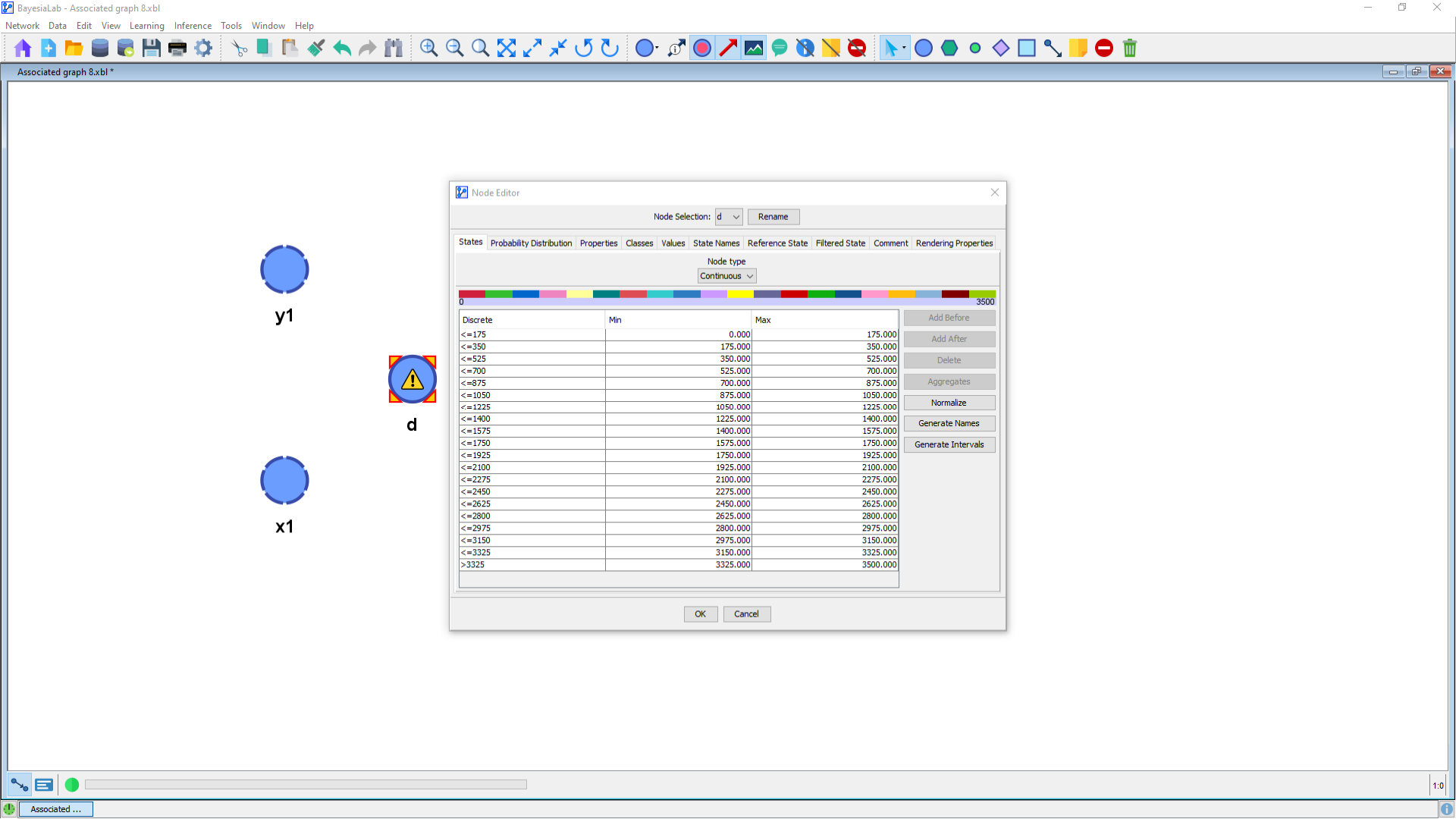
Associated graph 8.xbl *

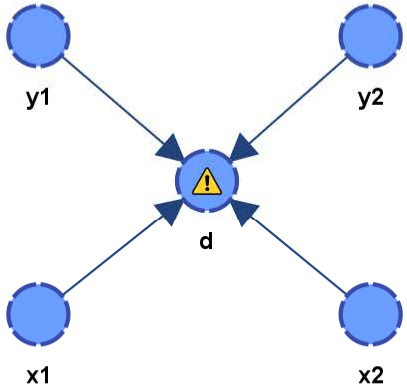


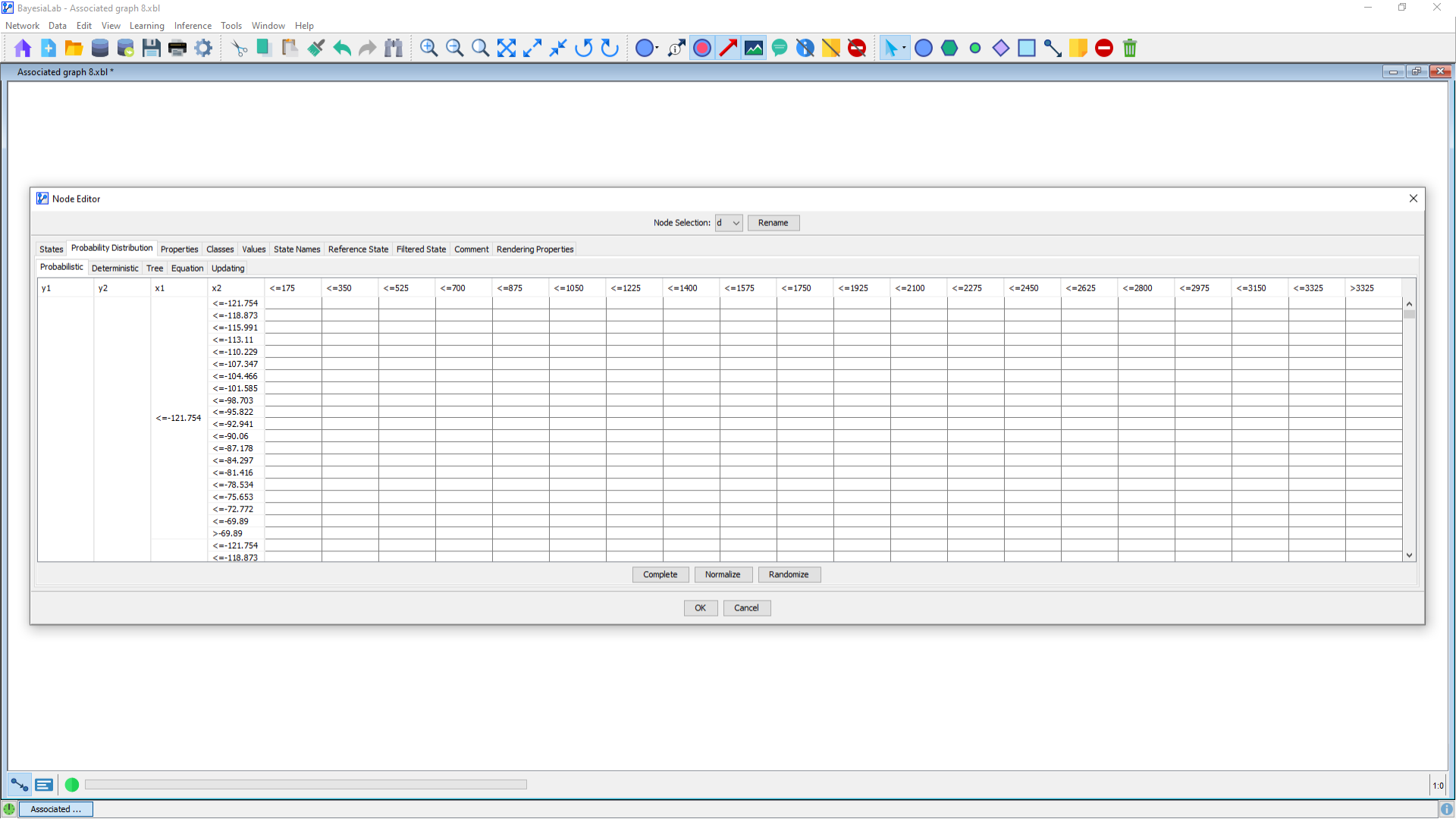
1:0

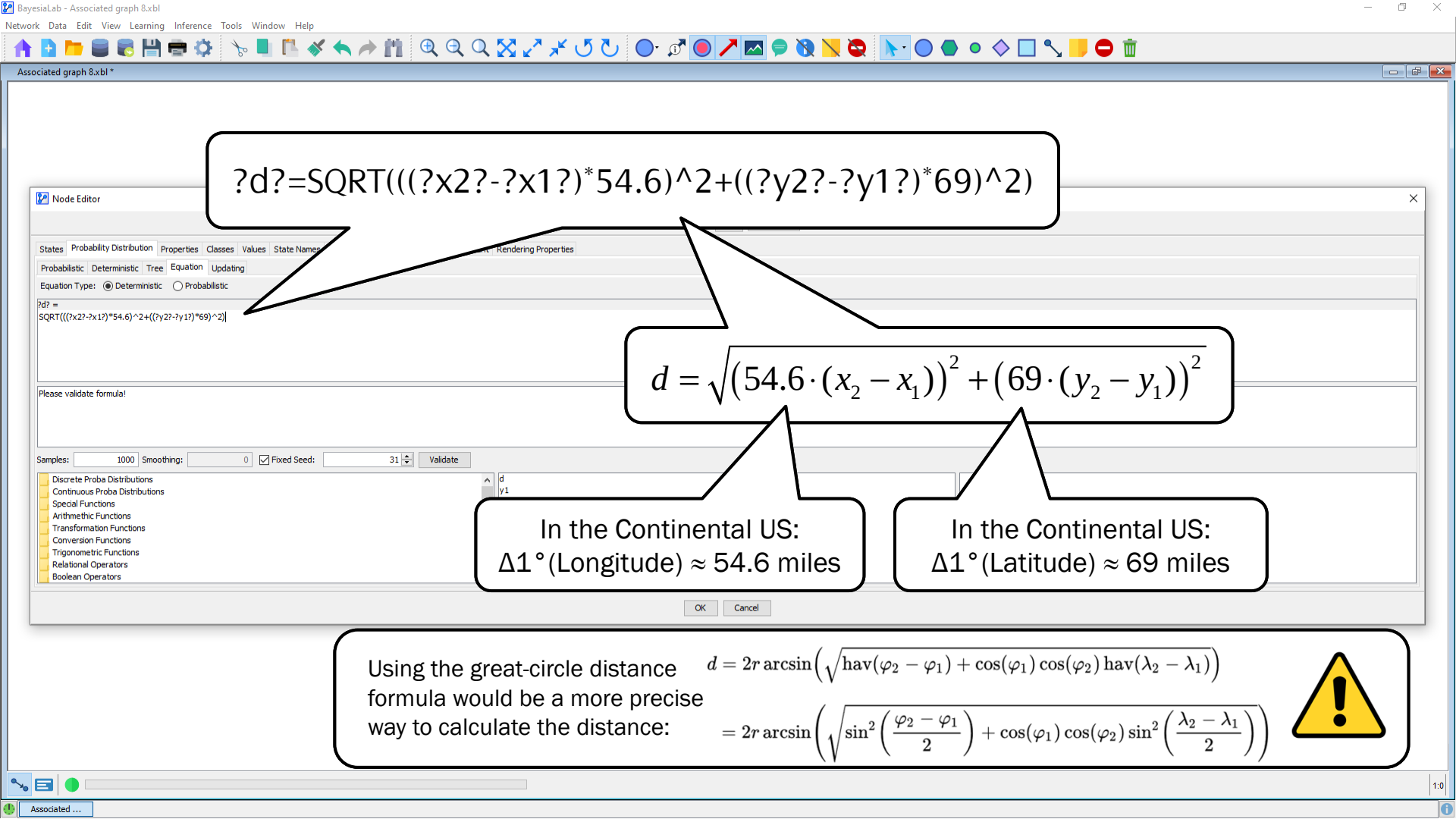
Associated ...


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
d
x1
Node Editor
Node Selection: d
Rename
States Probability Distribution Properties Classes Values State Names Reference State Filtered State Comment Rendering Properties
Node type
Continuous
0
1
Discrete Min Max
False 0.000 0.500
True 0.500 1.000
Add Before
Add After
Delete
Aggregates
Normalize
Generate Names
Generate Intervals
Generate Intervals
Number of Intervals: 20
Minimum 0 Maximum 3,500
Automatic Naming
Numbered Names Prefixed by : L
OK Cancel
OK Cancel
1:0
Associated ...


BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
y1
d
x1
Node Editor
Node Selection: d
Rename
States Probability Distribution Properties Classes Values State Names Reference State Filtered State Comment Rendering Properties
Node type
Continuous
0
3500
Discrete Min Max
<=175 0.000 175.000
<=350 175.000 350.000
<=525 350.000 525.000
<=700 525.000 700.000
<=875 700.000 875.000
<=1050 875.000 1050.000
<=1225 1050.000 1225.000
<=1400 1225.000 1400.000
<=1575 1400.000 1575.000
<=1750 1575.000 1750.000
<=1925 1750.000 1925.000
<=2100 1925.000 2100.000
<=2275 2100.000 2275.000
<=2450 2275.000 2450.000
<=2625 2450.000 2625.000
<=2800 2625.000 2800.000
<=2975 2800.000 2975.000
<=3150 2975.000 3150.000
<=3325 3150.000 3325.000
>3325 3325.000 3500.000
Add Before
Add After
Delete
Aggregates
Normalize
Generate Names
Generate Intervals
OK
Cancel
1:0
Associated ...


y1
y2
d
x1
x2

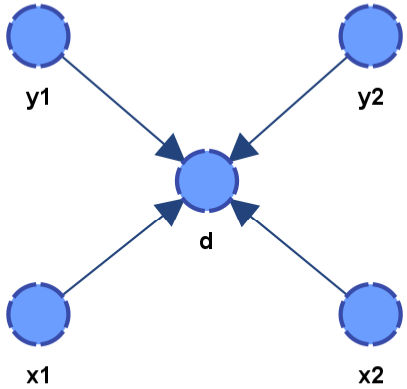

BayesiaLab - Associated graph 8.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 8.xbl *
Node Editor
Node Selection: d
Rename
States Probability Distribution Properties Classes Values State Names Reference State Filtered State Comment Rendering Properties
Probabilistic Deterministic Tree Equation Updating
y1 y2 x1 x2 <=175 <=350 <=525 <=700 <=875 <=1050 <=1225 <=1400 <=1575 <=1750 <=1925 <=2100 <=2275 <=2450 <=2625 <=2800 <=2975 <=3150 <=3325 >3325
<=-121.754
<=-118.873
<=-115.991
<=-113.11
<=-110.229
<=-107.347
<=-104.466
<=-101.585
<=-98.703
<=-95.822
<=-92.941
<=-90.06
<=-87.178
<=-84.297
<=-81.416
<=-78.534
<=-75.653
<=-72.772
<=-69.89
>-69.89
<=-121.754
<=-118.873
Complete
Normalize
Randomize
OK
Cancel
Associated ...
1:0


?d?=SQRT(((?x2?-?x1?)*54.6)^2+((?y2?-?y1?)*69)^2)
Node Editor
States
Probability Distribution
Properties
Classes
Values
State Names
Rendering Properties
Probabilistic
Deterministic
Tree
Equation
Updating
Equation Type:
Deterministic
Probabilistic
?d? =
SQRT(((?x2?-?x1?)*54.6)^2+((?y2?-?y1?)*69)^2)
Please validate formula!
Samples:
1000
Smoothing:
0
Fixed Seed:
31
Validate
Discrete Proba Distributions
Continuous Proba Distributions
Special Functions
Arithmetic Functions
Transformation Functions
Conversion Functions
Trigonometric Functions
Relational Operators
Boolean Operators
d
y1
OK
Cancel
$d = \sqrt{\left(54.6 \cdot (x_2 - x_1)\right)^2 + \left(69 \cdot (y_2 - y_1)\right)^2}$
In the Continental US:
Δ1°(Longitude) ≈ 54.6 miles
In the Continental US:
Δ1°(Latitude) ≈ 69 miles
Using the great-circle distance formula would be a more precise way to calculate the distance:
$d = 2r \arcsin\left(\sqrt{\operatorname{hav}(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\operatorname{hav}(\lambda_2 - \lambda_1)}\right)$
$= 2r \arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2)\sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl

Network Data Edit View Learning Inference Tools Window Help

Associated graph 8.xbl



0:0

Associated ...

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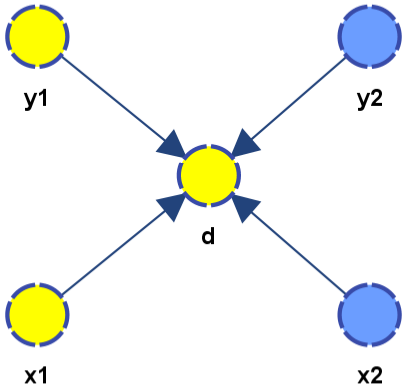
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 8.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Total Value: 998.580
Mean Value: 199.716

x1
Mean: -91.793 Dev: 15.679
Value: -91.748

5.46%	<=-121.754
3.29%	<=-118.873
7.40%	<=-115.991
1.12%	<=-113.11
2.93%	<=-110.229
0.46%	<=-107.347
2.37%	<=-104.466
0.67%	<=-101.585
0.84%	<=-98.703
6.93%	<=-95.822
6.50%	<=-92.941
4.34%	<=-90.06
8.01%	<=-87.178
8.05%	<=-84.297
11.32%	<=-81.416
8.97%	<=-78.534
6.99%	<=-75.653
10.51%	<=-72.772
3.63%	<=-69.89
0.20%	>-69.89

y1
Mean: 37.495 Dev: 4.997
Value: 37.495

0.49%	<=25.799
2.21%	<=27.036
1.88%	<=28.274
1.96%	<=29.511
5.48%	<=30.749
1.89%	<=31.986
5.96%	<=33.224
11.46%	<=34.461
5.94%	<=35.699
5.79%	<=36.936
5.85%	<=38.174
8.25%	<=39.411
10.63%	<=40.649
13.38%	<=41.886
9.35%	<=43.124
3.07%	<=44.361
2.95%	<=45.599
1.11%	<=46.836
2.00%	<=48.074
0.33%	>48.074

d
Mean: 1107.087 Dev: 696.795
Value: 1107.087

3.40%	<=175
8.22%	<=350
11.29%	<=525
12.36%	<=700
11.24%	<=875
9.32%	<=1050
7.55%	<=1225
6.23%	<=1400
4.98%	<=1575
4.40%	<=1750
4.36%	<=1925
4.39%	<=2100
4.01%	<=2275
3.54%	<=2450
2.53%	<=2625
1.57%	<=2800
0.53%	<=2975
0.07%	<=3150
0.00%	<=3325
0.00%	>3325

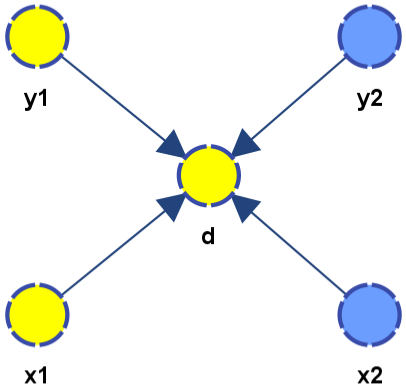
0:0

Associated ...

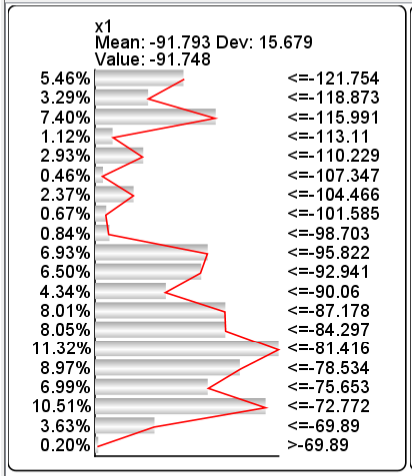
BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl

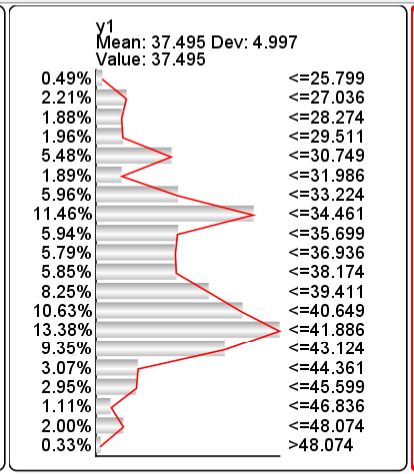
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

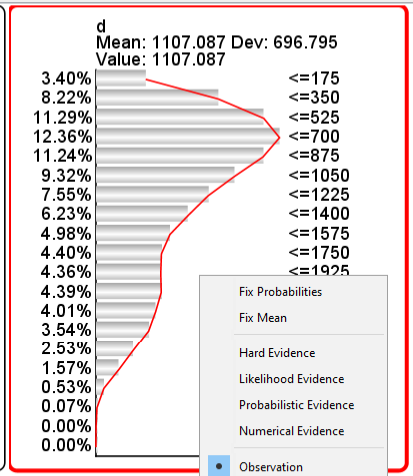
Associated graph 8.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Total Value: 998.580
Mean Value: 199.716

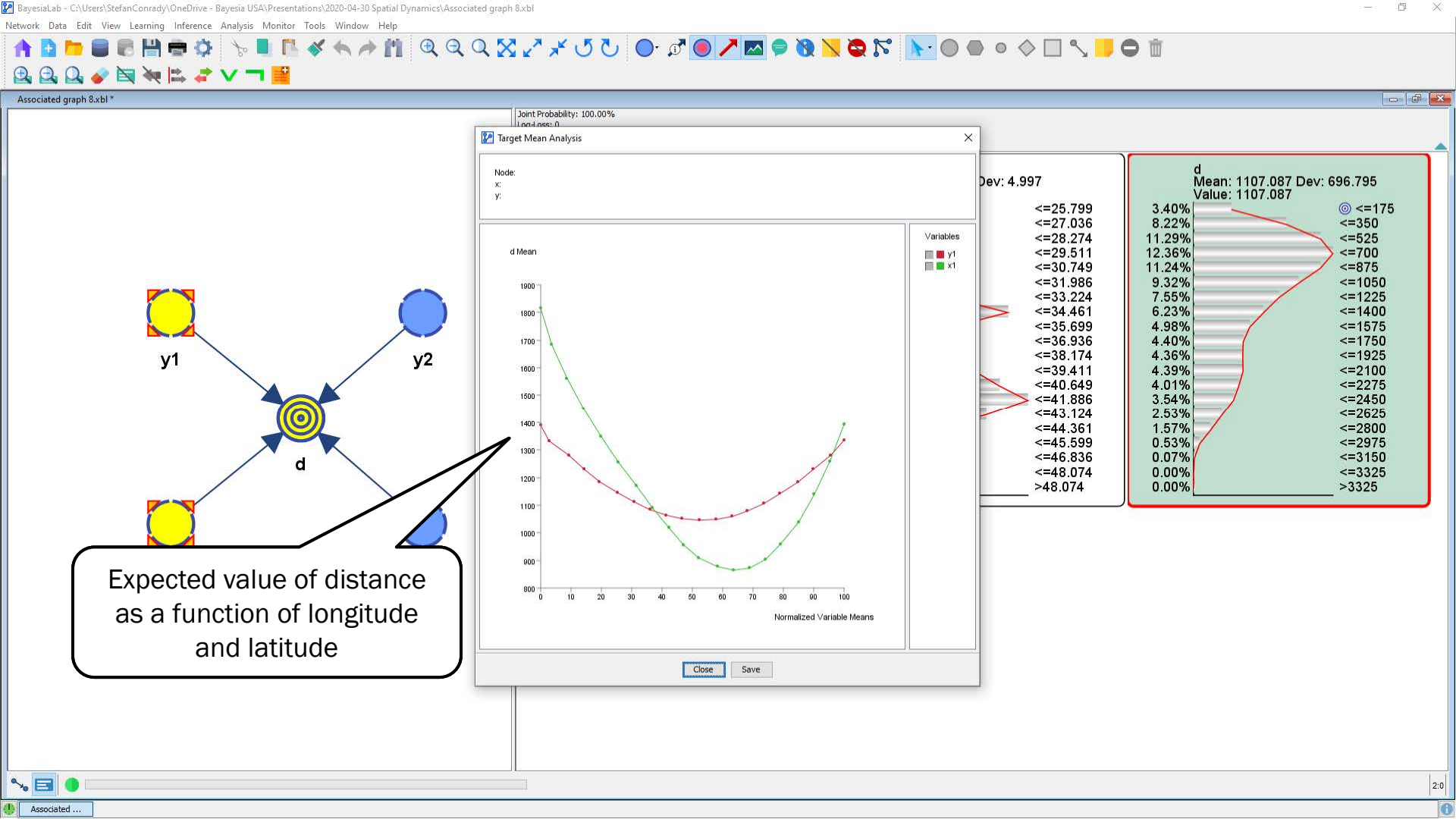


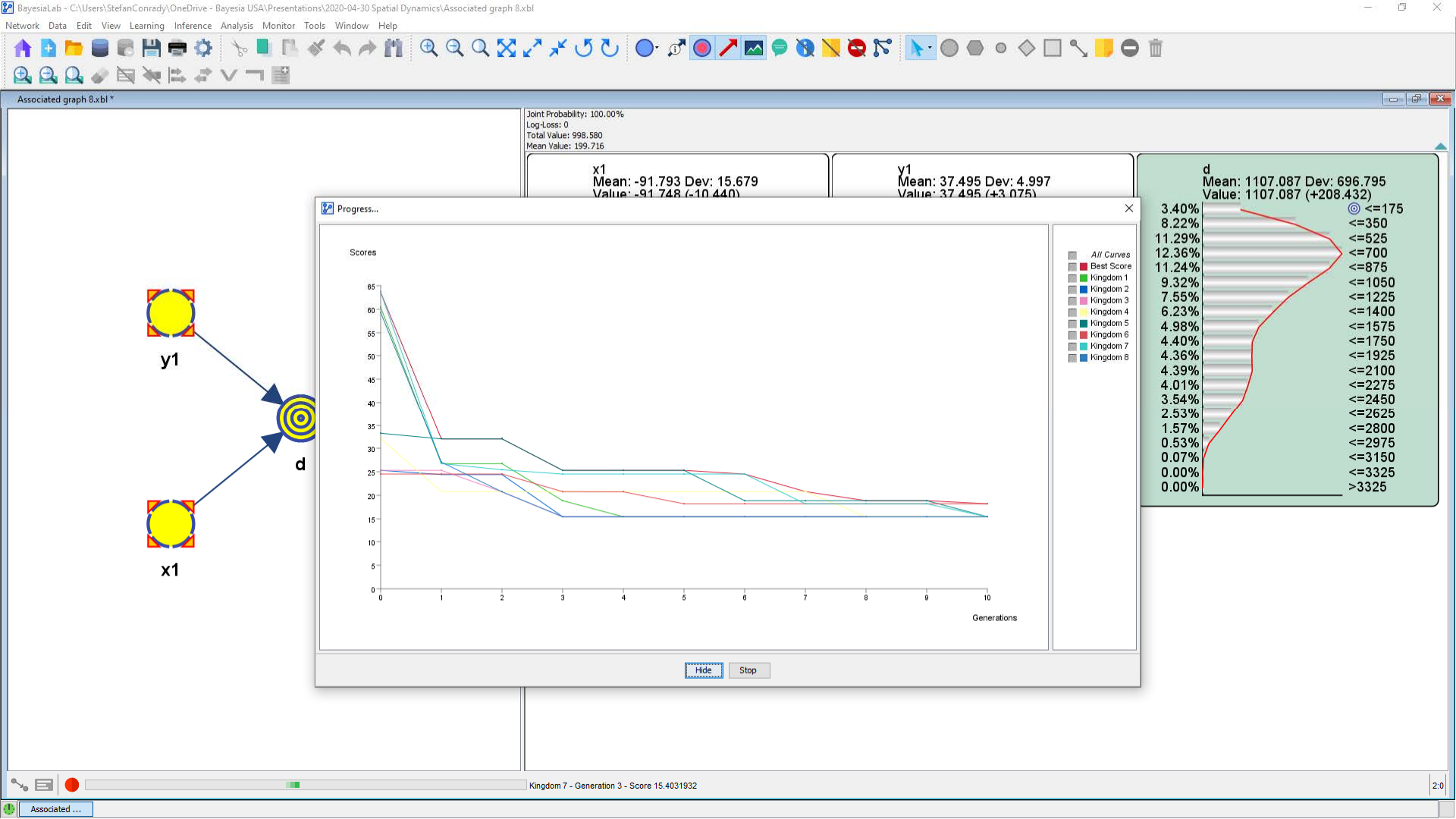




Fix Probabilities
Fix Mean
Hard Evidence
Likelihood Evidence
Probabilistic Evidence
Numerical Evidence
Observation
Intervention
Absolute Bars
Relative Bars
Relative Curve
Absolute Variations
Relative Variations
Show Probabilities
Show Expected Log-Loss
Copy
Delete

Associated ...


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Associated graph 8.xbl *
Joint Probability: 100.00%
Log-Loss: 0
y1
y2
d
Expected value of distance as a function of longitude and latitude
Target Mean Analysis
Node:
x:
y:
d Mean
Variables
y1
x1
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
0 10 20 30 40 50 60 70 80 90 100
Normalized Variable Means
Close
Save
Dev: 4.997
<=25.799
<=27.036
<=28.274
<=29.511
<=30.749
<=31.986
<=33.224
<=34.461
<=35.699
<=36.936
<=38.174
<=39.411
<=40.649
<=41.886
<=43.124
<=44.361
<=45.599
<=46.836
<=48.074
>48.074
d
Mean: 1107.087 Dev: 696.795
Value: 1107.087
3.40% <=175
8.22% <=350
11.29% <=525
12.36% <=700
11.24% <=875
9.32% <=1050
7.55% <=1225
6.23% <=1400
4.98% <=1575
4.40% <=1750
4.36% <=1925
4.39% <=2100
4.01% <=2275
3.54% <=2450
2.53% <=2625
1.57% <=2800
0.53% <=2975
0.07% <=3150
0.00% <=3325
0.00% >3325
Associated ...


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Associated graph 8.xbl *
Joint Probability: 100.00%
Log-Loss: 0
Total Value: 998.580
Mean Value: 199.716
x1
Mean: -91.793 Dev: 15.679
y1
Mean: 37.495 Dev: 4.997
d
Mean: 1107.087 Dev: 696.795
Value: 1107.087 (+208.432)
3.40% <=175
8.22% <=350
11.29% <=525
12.36% <=700
11.24% <=875
9.32% <=1050
7.55% <=1225
6.23% <=1400
4.98% <=1575
4.40% <=1750
4.36% <=1925
4.39% <=2100
4.01% <=2275
3.54% <=2450
2.53% <=2625
1.57% <=2800
0.53% <=2975
0.07% <=3150
0.00% <=3325
0.00% >3325
y1
d
x1
Progress...
Scores
All Curves
Best Score
Kingdom 1
Kingdom 2
Kingdom 3
Kingdom 4
Kingdom 5
Kingdom 6
Kingdom 7
Kingdom 8
Generations
Hide
Stop
Kingdom 7 - Generation 3 - Score 15.4031932
Associated ...

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 8.xbl *

Joint Probability: 100.00%
Log-Loss: 0
Total Value: 998.580
Mean Value: 199.716

x1
Mean: -91.793 Dev: 15.679
Value: -91.748 (-10.440)

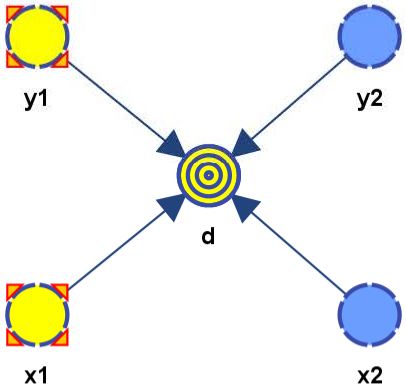
5.46%	<=-121.754
3.29%	<=-118.873
7.40%	<=-115.991

y1
Mean: 37.495 Dev: 4.997
Value: 37.495 (+3.075)

0.49%	<=25.799
2.21%	<=27.036
1.88%	<=28.274
	<=29.511
	<=30.749
	<=31.986
	<=33.224
	<=34.461
	<=35.699
	<=36.936
	<=38.174
	<=39.411
	<=40.649
	<=41.886
	<=43.124
	<=44.361
	<=45.599
	<=46.836
	<=48.074
	>48.074

d
Mean: 1107.087 Dev: 696.795
Value: 1107.087 (+208.432)

3.40%	<=175
8.22%	<=350
11.29%	<=525
12.36%	<=700
11.24%	<=875
9.32%	<=1050
7.55%	<=1225
6.23%	<=1400
4.98%	<=1575
4.40%	<=1750
4.36%	<=1925
4.39%	<=2100
4.01%	<=2275
3.54%	<=2450
2.53%	<=2625
1.57%	<=2800
0.53%	<=2975
0.07%	<=3150
0.00%	<=3325
0.00%	>3325



Optimization Report of d (Associated graph 8)

Analysis Context

No Observation

Initial State

Value/Mean	Joint Probability
1,107.0866	100.0000%

Search Method: Hard Evidence

Synthesis

Nodes	x1	y1
Initial Value	-91.7479	37.4946
Best Solution	-82.8088 (8.9391)	41.1792 (3.6846)
Min	-91.7479 (0.0000)	33.8663 (-3.6283)
Max	-74.2079 (17.5401)	42.4677 (4.9731)

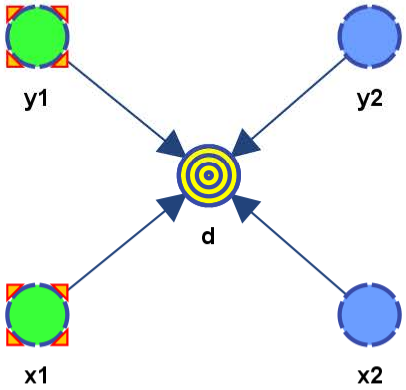
Close

Associated ...

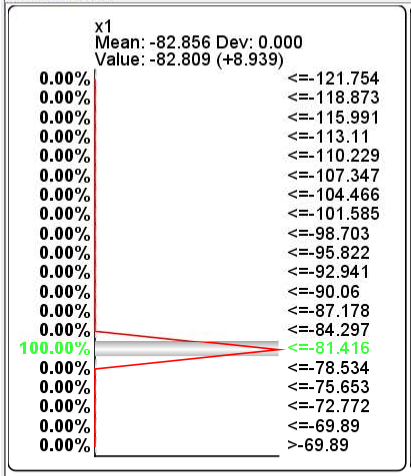
BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Associated graph 8.xbl

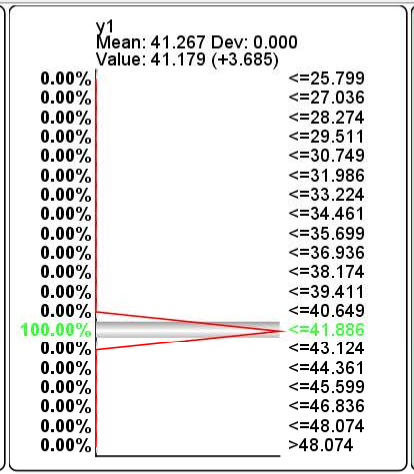
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

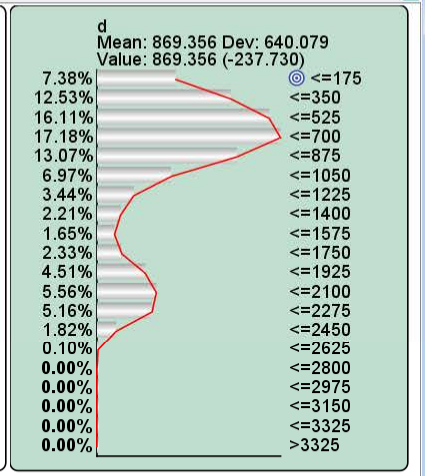
Associated graph 8.xbl *



Joint Probability: 1.51%
Log-Loss: 6.05
Total Value: 773.473
Mean Value: 154.695







Select an evidence set

Index	Comment
0	GA Score: 15.4031932
1	GA Score: 18.177061
2	GA Score: 18.8420802
3	GA Score: 20.7291169
4	GA Score: 20.7884891
5	GA Score: 20.8185179
6	GA Score: 21.6674884
7	GA Score: 22.9615237
8	GA Score: 23.8758095
9	GA Score: 24.4250777

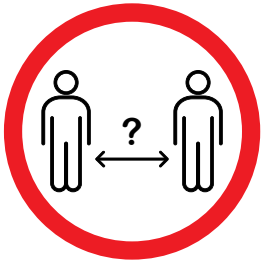
10 Rows Include Not Observable

GA Score: 15.4031932

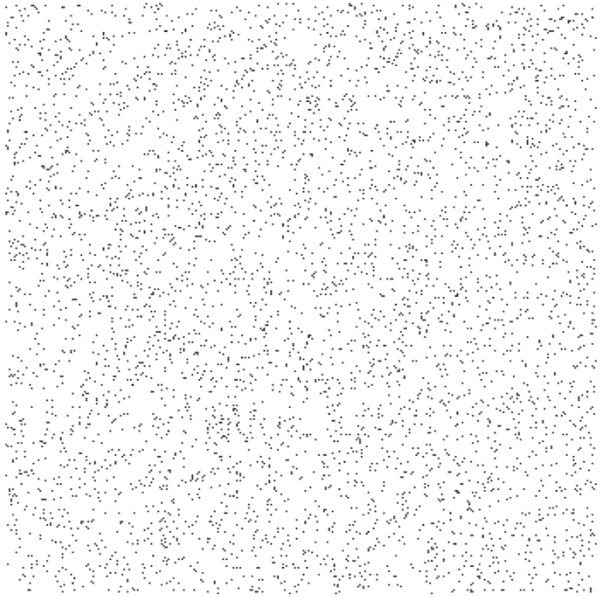
2:0

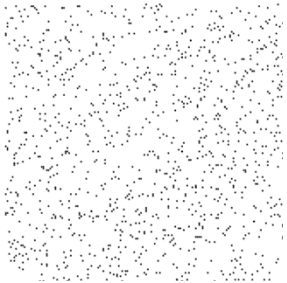
Associated ...

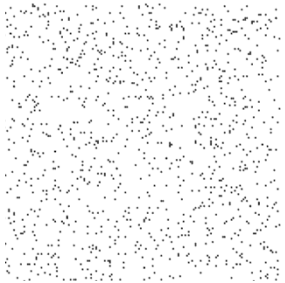
Bayesian Network

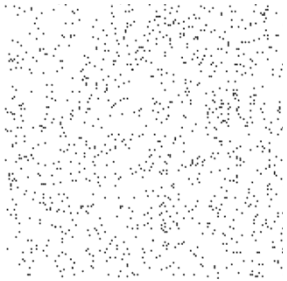


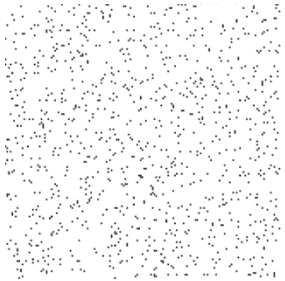
How to distance?

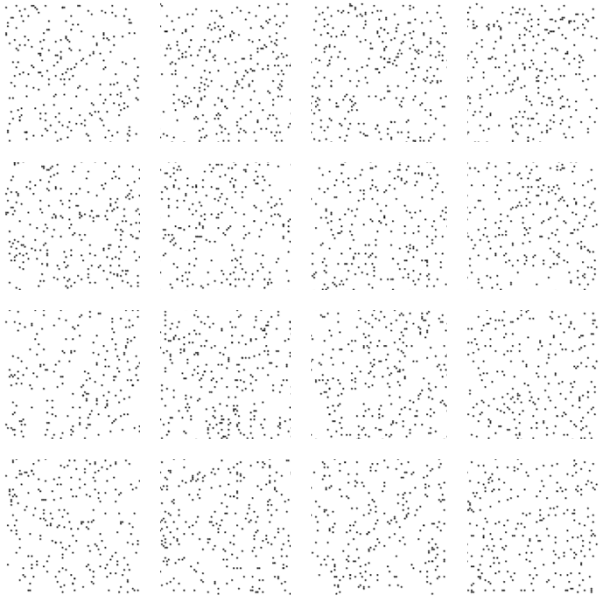








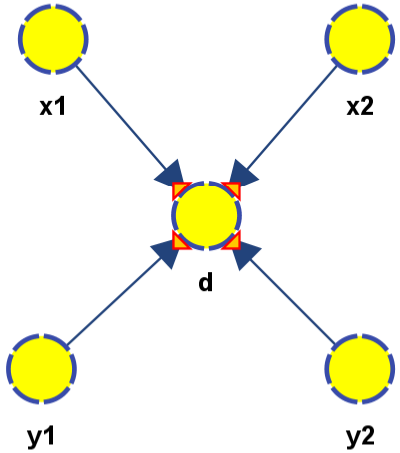




BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Distances2.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances2.xbl



Joint Probability: 100.00%
Log-Loss: 0
Total Value: 2.521
Mean Value: 0.504

x1
Mean: 0.500 Dev: 0.288
Value: 0.500

5.00%	<=0.05
5.00%	<=0.1
5.00%	<=0.15
5.00%	<=0.2
5.00%	<=0.25
5.00%	<=0.3
5.00%	<=0.35
5.00%	<=0.4
5.00%	<=0.45
5.00%	<=0.5
5.00%	<=0.55
5.00%	<=0.6
5.00%	<=0.65
5.00%	<=0.7
5.00%	<=0.75
5.00%	<=0.8
5.00%	<=0.85
5.00%	<=0.9
5.00%	<=0.95
5.00%	>0.95

y1
Mean: 0.500 Dev: 0.288
Value: 0.500

5.00%	<=0.05
5.00%	<=0.1
5.00%	<=0.15
5.00%	<=0.2
5.00%	<=0.25
5.00%	<=0.3
5.00%	<=0.35
5.00%	<=0.4
5.00%	<=0.45
5.00%	<=0.5
5.00%	<=0.55
5.00%	<=0.6
5.00%	<=0.65
5.00%	<=0.7
5.00%	<=0.75
5.00%	<=0.8
5.00%	<=0.85
5.00%	<=0.9
5.00%	<=0.95
5.00%	>0.95

d
Mean: 0.521 Dev: 0.250
Value: 0.521

2.88%	<=0.1
7.63%	<=0.2
10.97%	<=0.3
13.00%	<=0.4
13.85%	<=0.5
13.65%	<=0.6
12.50%	<=0.7
10.53%	<=0.8
7.87%	<=0.9
4.62%	<=1
1.76%	<=1.1
0.60%	<=1.2
0.14%	<=1.3
0.01%	<=1.4
0.00%	>1.4

x2
Mean: 0.500 Dev: 0.288
Value: 0.500

5.00%	<=0.05
5.00%	<=0.1
5.00%	<=0.15
5.00%	<=0.2
5.00%	<=0.25
5.00%	<=0.3
5.00%	<=0.35
5.00%	<=0.4
5.00%	<=0.45
5.00%	<=0.5
5.00%	<=0.55
5.00%	<=0.6
5.00%	<=0.65
5.00%	<=0.7
5.00%	<=0.75
5.00%	<=0.8
5.00%	<=0.85
5.00%	<=0.9
5.00%	<=0.95
5.00%	>0.95

y2
Mean: 0.500 Dev: 0.288
Value: 0.500

5.00%	<=0.05
5.00%	<=0.1
5.00%	<=0.15
5.00%	<=0.2
5.00%	<=0.25
5.00%	<=0.3
5.00%	<=0.35
5.00%	<=0.4
5.00%	<=0.45
5.00%	<=0.5
5.00%	<=0.55
5.00%	<=0.6
5.00%	<=0.65
5.00%	<=0.7
5.00%	<=0.75
5.00%	<=0.8
5.00%	<=0.85
5.00%	<=0.9
5.00%	<=0.95
5.00%	>0.95

1:0

Distances2....

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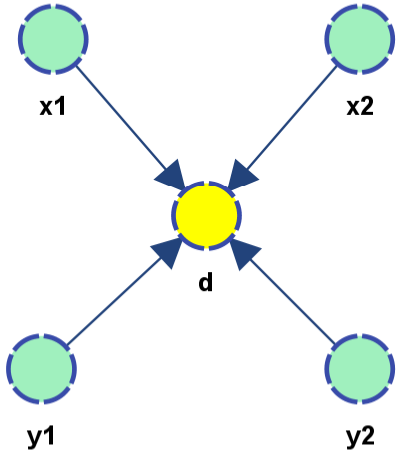
Distances2.xbl



Joint Probability: 65.61%
Log-Loss: 0.61
Total Value: 2.550
Mean Value: 0.510

x1
Mean: 0.500 Dev: 0.304
Value: 0.500 (+0.000)

5.56%	<=0.05
5.56%	<=0.1
5.56%	<=0.15
5.56%	<=0.2
5.56%	<=0.25
5.56%	<=0.3
5.56%	<=0.35
5.56%	<=0.4
5.56%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
5.56%	<=0.6
5.56%	<=0.65
5.56%	<=0.7
5.56%	<=0.75
5.56%	<=0.8
5.56%	<=0.85
5.56%	<=0.9
5.56%	<=0.95
5.56%	>0.95

y1
Mean: 0.500 Dev: 0.304
Value: 0.500 (-0.000)

5.56%	<=0.05
5.56%	<=0.1
5.56%	<=0.15
5.56%	<=0.2
5.56%	<=0.25
5.56%	<=0.3
5.56%	<=0.35
5.56%	<=0.4
5.56%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
5.56%	<=0.6
5.56%	<=0.65
5.56%	<=0.7
5.56%	<=0.75
5.56%	<=0.8
5.56%	<=0.85
5.56%	<=0.9
5.56%	<=0.95
5.56%	>0.95

d
Mean: 0.550 Dev: 0.262
Value: 0.550 (+0.007)

3.18%	<=0.1
7.46%	<=0.2
9.98%	<=0.3
11.03%	<=0.4
11.05%	<=0.5
13.00%	<=0.6
13.51%	<=0.7
11.99%	<=0.8
9.39%	<=0.9
5.80%	<=1
2.46%	<=1.1
0.91%	<=1.2
0.21%	<=1.3
0.02%	<=1.4
0.00%	>1.4

x2
Mean: 0.500 Dev: 0.304
Value: 0.500 (+0.000)

5.56%	<=0.05
5.56%	<=0.1
5.56%	<=0.15
5.56%	<=0.2
5.56%	<=0.25
5.56%	<=0.3
5.56%	<=0.35
5.56%	<=0.4
5.56%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
5.56%	<=0.6
5.56%	<=0.65
5.56%	<=0.7
5.56%	<=0.75
5.56%	<=0.8
5.56%	<=0.85
5.56%	<=0.9
5.56%	<=0.95
5.56%	>0.95

y2
Mean: 0.500 Dev: 0.304
Value: 0.500

5.56%	<=0.05
5.56%	<=0.1
5.56%	<=0.15
5.56%	<=0.2
5.56%	<=0.25
5.56%	<=0.3
5.56%	<=0.35
5.56%	<=0.4
5.56%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
5.56%	<=0.6
5.56%	<=0.65
5.56%	<=0.7
5.56%	<=0.75
5.56%	<=0.8
5.56%	<=0.85
5.56%	<=0.9
5.56%	<=0.95
5.56%	>0.95

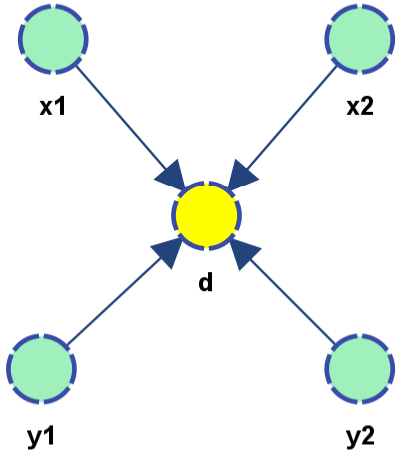
0:0

Distances2....

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Presentations\2020-04-30 Spatial Dynamics\Distances2.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances2.xbl *



Joint Probability: 12.96%
Log-Loss: 2.95
Total Value: 2.571
Mean Value: 0.514

x1
Mean: 0.500 Dev: 0.316
Value: 0.500

8.33%	<=0.05
8.33%	<=0.1
8.33%	<=0.15
0.00%	<=0.2
0.00%	<=0.25
0.00%	<=0.3
8.33%	<=0.35
8.33%	<=0.4
8.33%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
8.33%	<=0.6
8.33%	<=0.65
8.33%	<=0.7
0.00%	<=0.75
0.00%	<=0.8
0.00%	<=0.85
8.33%	<=0.9
8.33%	<=0.95
8.33%	>0.95

y1
Mean: 0.500 Dev: 0.316
Value: 0.500

8.33%	<=0.05
8.33%	<=0.1
8.33%	<=0.15
0.00%	<=0.2
0.00%	<=0.25
0.00%	<=0.3
8.33%	<=0.35
8.33%	<=0.4
8.33%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
8.33%	<=0.6
8.33%	<=0.65
8.33%	<=0.7
0.00%	<=0.75
0.00%	<=0.8
0.00%	<=0.85
8.33%	<=0.9
8.33%	<=0.95
8.33%	>0.95

d
Mean: 0.571 Dev: 0.274
Value: 0.571

4.40%	<=0.1
3.49%	<=0.2
9.54%	<=0.3
13.17%	<=0.4
10.44%	<=0.5
14.41%	<=0.6
13.41%	<=0.7
7.19%	<=0.8
10.15%	<=0.9
8.08%	<=1
3.71%	<=1.1
1.19%	<=1.2
0.73%	<=1.3
0.09%	<=1.4
0.00%	>1.4

x2
Mean: 0.500 Dev: 0.316
Value: 0.500

8.33%	<=0.05
8.33%	<=0.1
8.33%	<=0.15
0.00%	<=0.2
0.00%	<=0.25
0.00%	<=0.3
8.33%	<=0.35
8.33%	<=0.4
8.33%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
8.33%	<=0.6
8.33%	<=0.65
8.33%	<=0.7
0.00%	<=0.75
0.00%	<=0.8
0.00%	<=0.85
8.33%	<=0.9
8.33%	<=0.95
8.33%	>0.95

y2
Mean: 0.500 Dev: 0.316
Value: 0.500

8.33%	<=0.05
8.33%	<=0.1
8.33%	<=0.15
0.00%	<=0.2
0.00%	<=0.25
0.00%	<=0.3
8.33%	<=0.35
8.33%	<=0.4
8.33%	<=0.45
0.00%	<=0.5
0.00%	<=0.55
8.33%	<=0.6
8.33%	<=0.65
8.33%	<=0.7
0.00%	<=0.75
0.00%	<=0.8
0.00%	<=0.85
8.33%	<=0.9
8.33%	<=0.95
8.33%	>0.95

Distances2....

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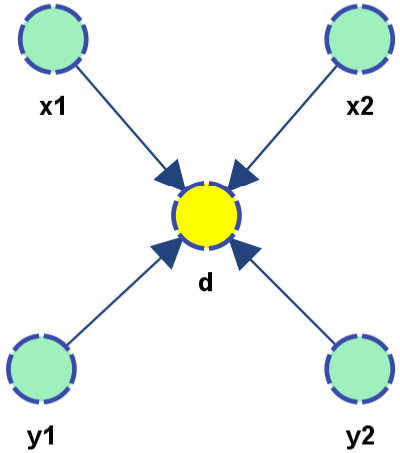
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances2.xbl



Joint Probability: 6.25%
Log-Loss: 4
Total Value: 2.423
Mean Value: 0.485

x1
Mean: 0.475 Dev: 0.287
Value: 0.475 (+0.000)

10.00%	<=0.05
0.00%	<=0.1
10.00%	<=0.15
0.00%	<=0.2
10.00%	<=0.25
0.00%	<=0.3
10.00%	<=0.35
0.00%	<=0.4
10.00%	<=0.45
0.00%	<=0.5
10.00%	<=0.55
0.00%	<=0.6
10.00%	<=0.65
0.00%	<=0.7
10.00%	<=0.75
0.00%	<=0.8
10.00%	<=0.85
0.00%	<=0.9
10.00%	<=0.95
0.00%	>0.95

y1
Mean: 0.475 Dev: 0.287
Value: 0.475 (-0.000)

10.00%	<=0.05
0.00%	<=0.1
10.00%	<=0.15
0.00%	<=0.2
10.00%	<=0.25
0.00%	<=0.3
10.00%	<=0.35
0.00%	<=0.4
10.00%	<=0.45
0.00%	<=0.5
10.00%	<=0.55
0.00%	<=0.6
10.00%	<=0.65
0.00%	<=0.7
10.00%	<=0.75
0.00%	<=0.8
10.00%	<=0.85
0.00%	<=0.9
10.00%	<=0.95
0.00%	>0.95

d
Mean: 0.523 Dev: 0.248
Value: 0.523 (+0.001)

2.71%	<=0.1
7.37%	<=0.2
11.17%	<=0.3
12.94%	<=0.4
13.86%	<=0.5
13.86%	<=0.6
12.40%	<=0.7
10.76%	<=0.8
7.87%	<=0.9
4.74%	<=1
1.66%	<=1.1
0.53%	<=1.2
0.13%	<=1.3
0.00%	<=1.4
0.00%	>1.4

x2
Mean: 0.475 Dev: 0.287
Value: 0.475 (-0.000)

10.00%	<=0.05
0.00%	<=0.1
10.00%	<=0.15
0.00%	<=0.2
10.00%	<=0.25
0.00%	<=0.3
10.00%	<=0.35
0.00%	<=0.4
10.00%	<=0.45
0.00%	<=0.5
10.00%	<=0.55
0.00%	<=0.6
10.00%	<=0.65
0.00%	<=0.7
10.00%	<=0.75
0.00%	<=0.8
10.00%	<=0.85
0.00%	<=0.9
10.00%	<=0.95
0.00%	>0.95

y2
Mean: 0.475 Dev: 0.287
Value: 0.475 (-0.025)

10.00%	<=0.05
0.00%	<=0.1
10.00%	<=0.15
0.00%	<=0.2
10.00%	<=0.25
0.00%	<=0.3
10.00%	<=0.35
0.00%	<=0.4
10.00%	<=0.45
0.00%	<=0.5
10.00%	<=0.55
0.00%	<=0.6
10.00%	<=0.65
0.00%	<=0.7
10.00%	<=0.75
0.00%	<=0.8
10.00%	<=0.85
0.00%	<=0.9
10.00%	<=0.95
0.00%	>0.95

0:0

Distances2....

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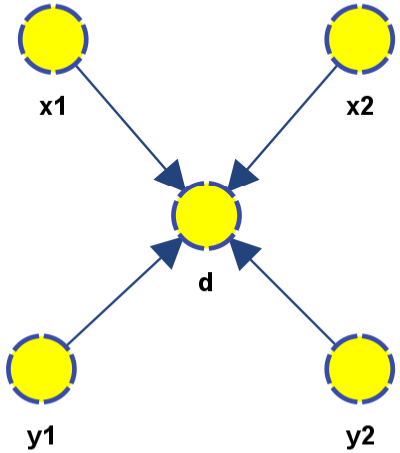
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Distances2.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Total Value: 2.521
Mean Value: 0.504

x1
Mean: 0.457 Dev: 0.316
Value: 0.457

9.35%	<=0.05
7.63%	<=0.1
9.37%	<=0.15
3.64%	<=0.2
7.20%	<=0.25
2.83%	<=0.3
1.70%	<=0.35
4.59%	<=0.4
2.54%	<=0.45
4.38%	<=0.5
1.63%	<=0.55
8.66%	<=0.6
7.79%	<=0.65
5.84%	<=0.7
1.31%	<=0.75
2.11%	<=0.8
0.59%	<=0.85
7.73%	<=0.9
1.58%	<=0.95
9.53%	>0.95

y1
Mean: 0.526 Dev: 0.298
Value: 0.526

1.36%	<=0.05
5.56%	<=0.1
5.78%	<=0.15
5.97%	<=0.2
5.80%	<=0.25
6.81%	<=0.3
5.35%	<=0.35
8.53%	<=0.4
0.52%	<=0.45
0.62%	<=0.5
1.46%	<=0.55
7.98%	<=0.6
2.42%	<=0.65
2.12%	<=0.7
7.56%	<=0.75
9.82%	<=0.8
2.18%	<=0.85
7.65%	<=0.9
6.25%	<=0.95
6.24%	>0.95

d
Mean: 0.555 Dev: 0.267
Value: 0.555

3.45%	<=0.1
7.29%	<=0.2
9.24%	<=0.3
10.61%	<=0.4
11.87%	<=0.5
13.19%	<=0.6
12.91%	<=0.7
11.30%	<=0.8
9.65%	<=0.9
6.29%	<=1
2.76%	<=1.1
1.12%	<=1.2
0.29%	<=1.3
0.02%	<=1.4
0.00%	>1.4

x2
Mean: 0.457 Dev: 0.316
Value: 0.457

9.35%	<=0.05
7.63%	<=0.1
9.37%	<=0.15
3.64%	<=0.2
7.20%	<=0.25
2.83%	<=0.3
1.70%	<=0.35
4.59%	<=0.4
2.54%	<=0.45
4.38%	<=0.5
1.63%	<=0.55
8.66%	<=0.6
7.79%	<=0.65
5.84%	<=0.7
1.31%	<=0.75
2.11%	<=0.8
0.59%	<=0.85
7.73%	<=0.9
1.58%	<=0.95
9.53%	>0.95

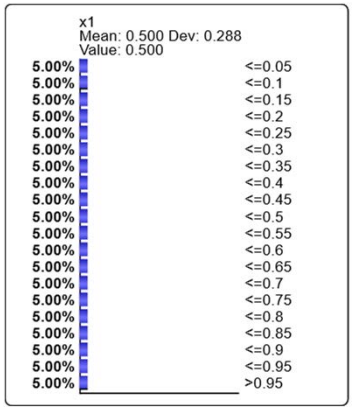
y2
Mean: 0.526 Dev: 0.298
Value: 0.526

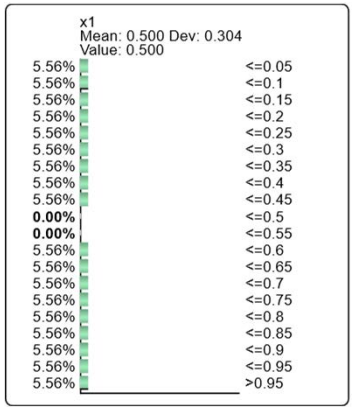
1.36%	<=0.05
5.56%	<=0.1
5.78%	<=0.15
5.97%	<=0.2
5.80%	<=0.25
6.81%	<=0.3
5.35%	<=0.35
8.53%	<=0.4
0.52%	<=0.45
0.62%	<=0.5
1.46%	<=0.55
7.98%	<=0.6
2.42%	<=0.65
2.12%	<=0.7
7.56%	<=0.75
9.82%	<=0.8
2.18%	<=0.85
7.65%	<=0.9
6.25%	<=0.95
6.24%	>0.95

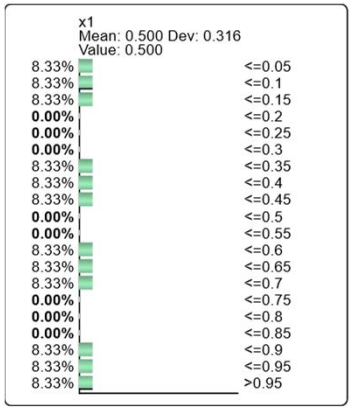
Distances2....

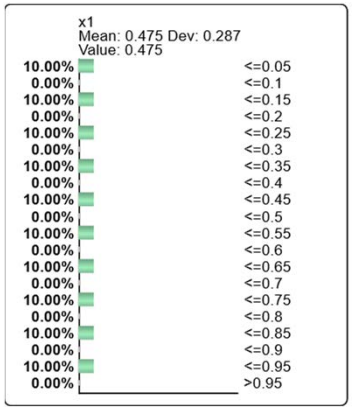
Simulation of Distancing Scenarios

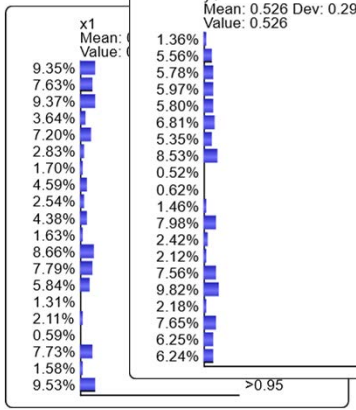
Comparison of Patterns

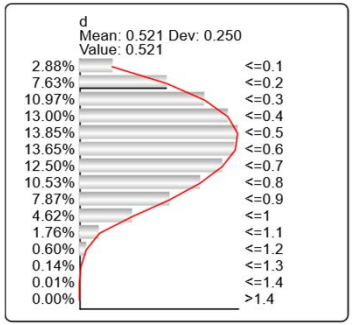


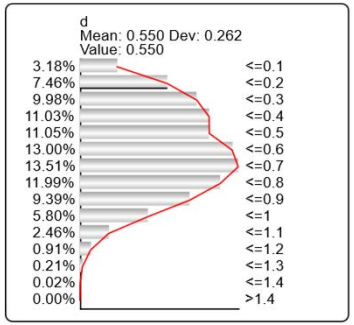


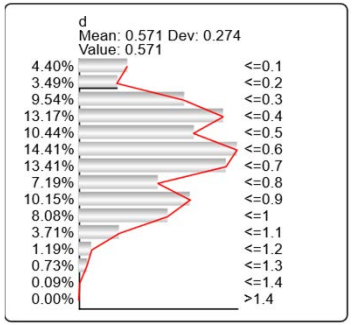


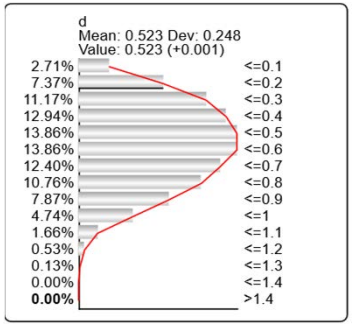


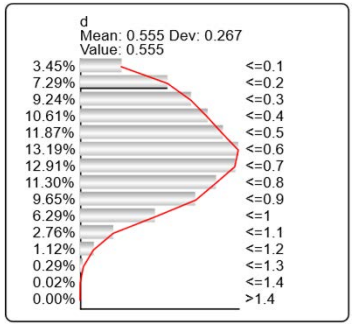












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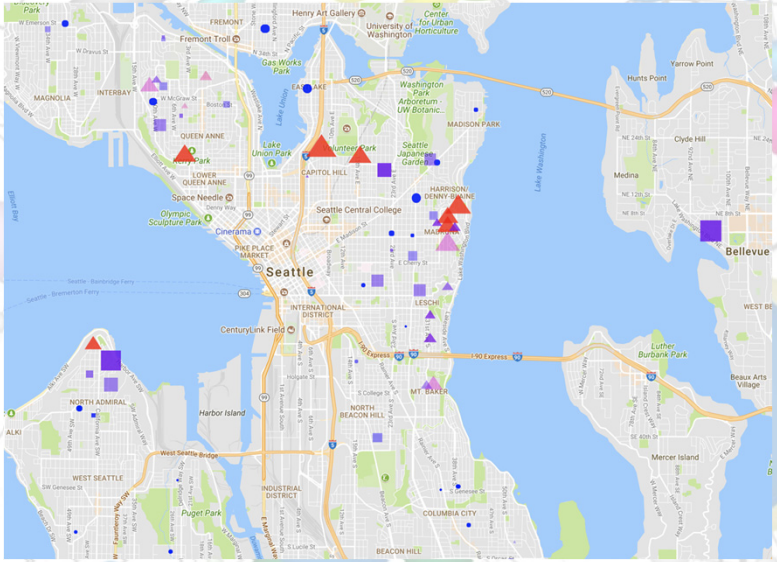
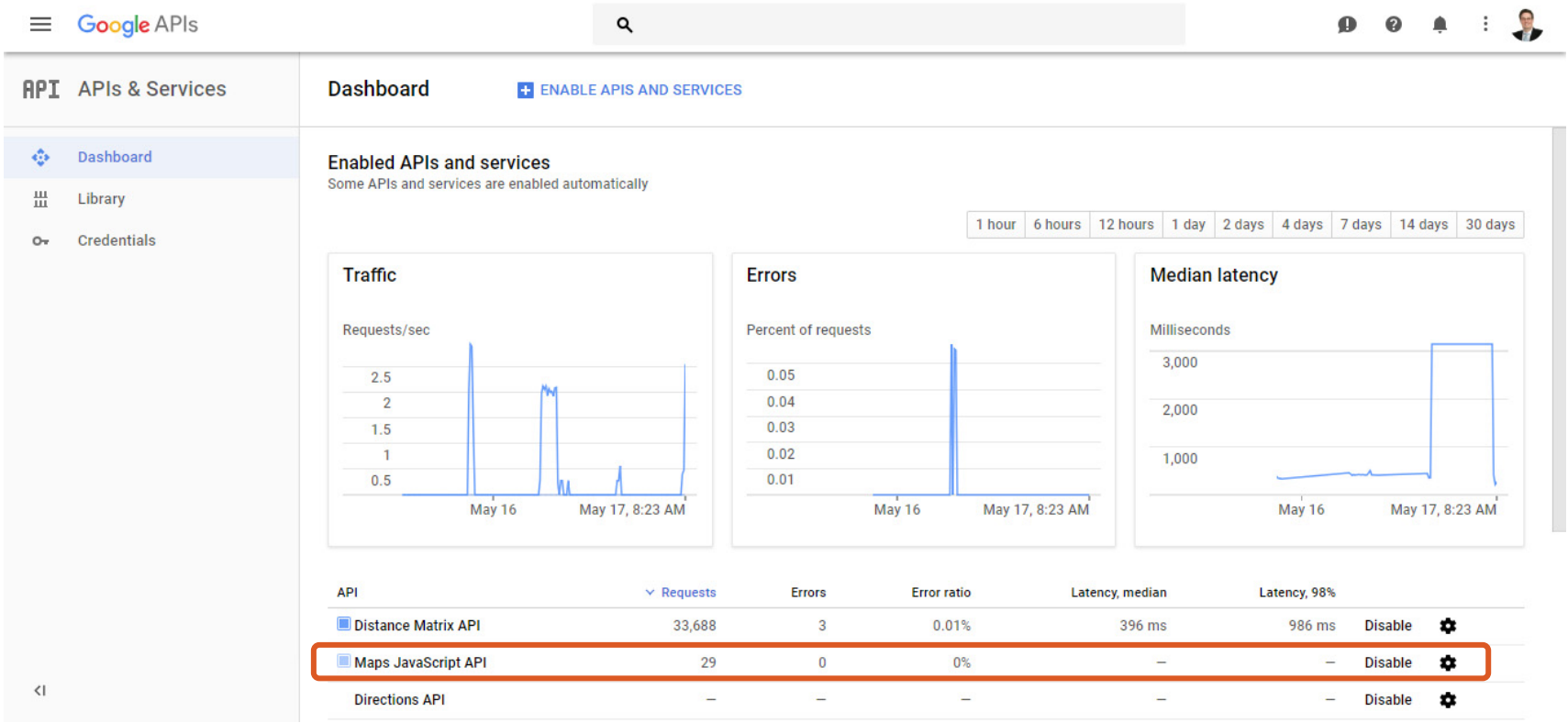
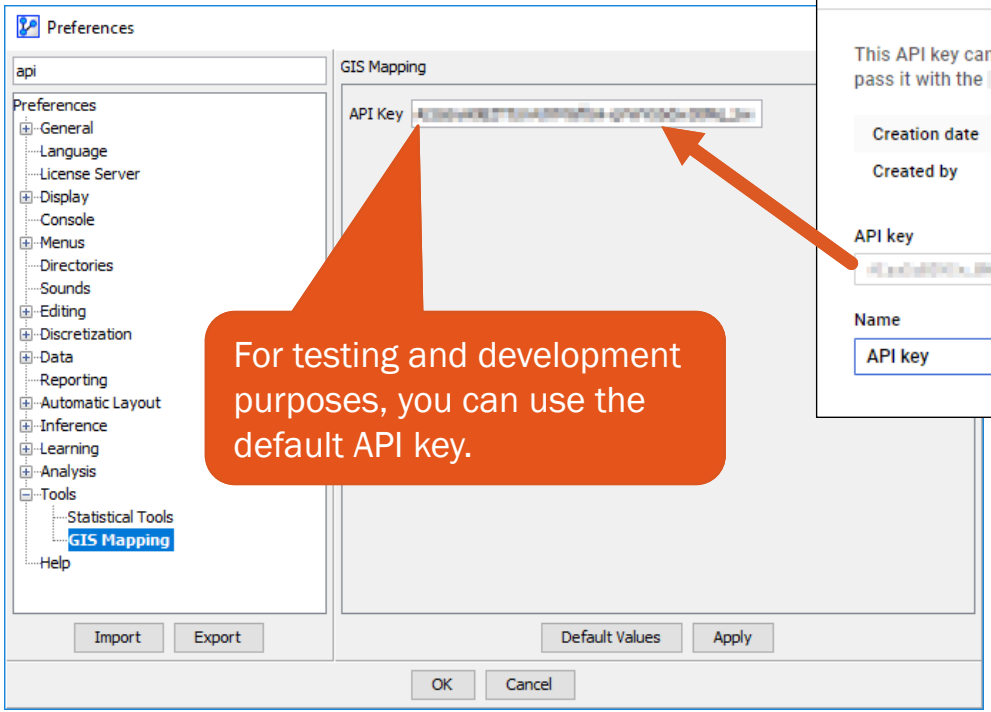


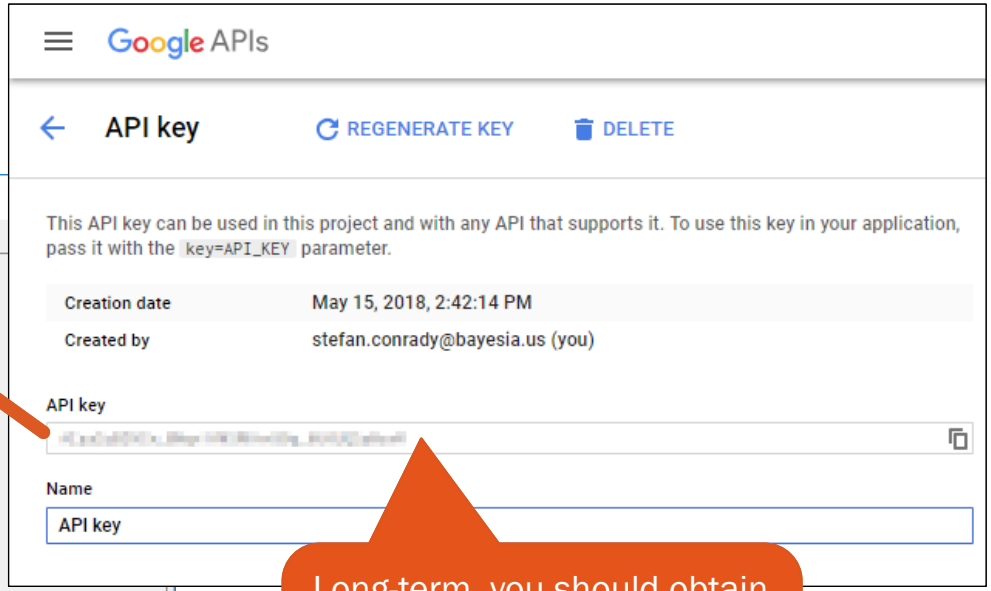
GIS Mapping with BayesiaLab and the Google API

Google Maps JavaScript API



BayesiaLab Setup





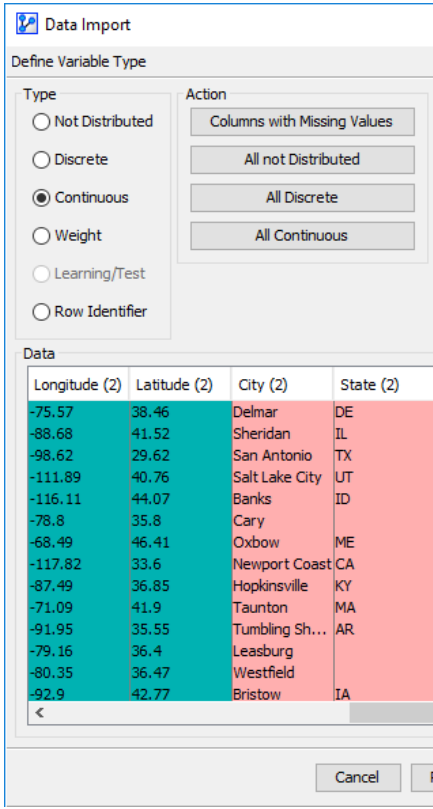
For testing and development purposes, you can use the default API key.

Long-term, you should obtain your own Google API key so you are not subject to any API call limitations.

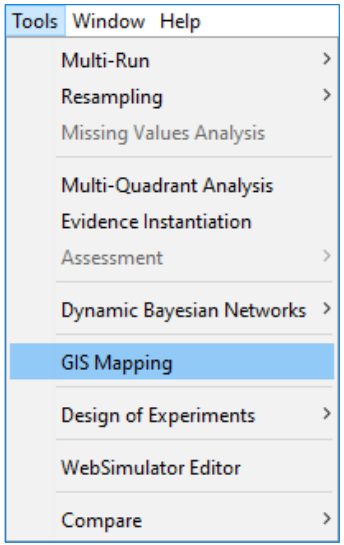
GIS Mapping with BayesiaLab and the Google API

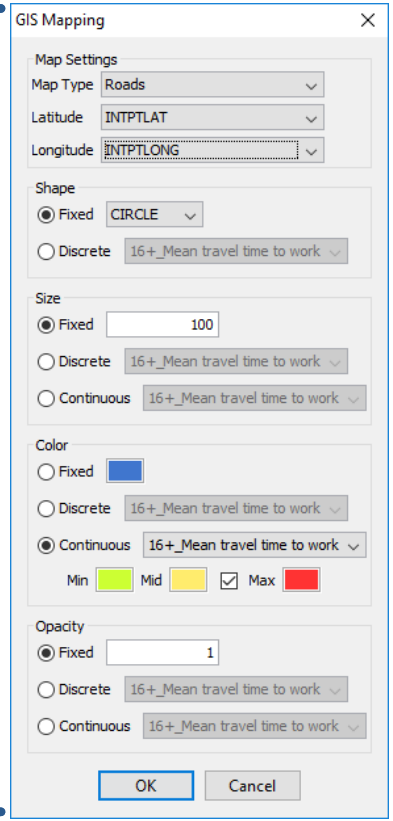
The Basics

- BayesiaLab can display observed or inferred values with coordinates on a Google map.
- Longitude and latitude are used as coordinates.
- Longitude and latitude must be defined as continuous variables and **discretized** during import, even though they will be used as **undiscretized** values for map display.



GIS Mapping with BayesiaLab and the Google API



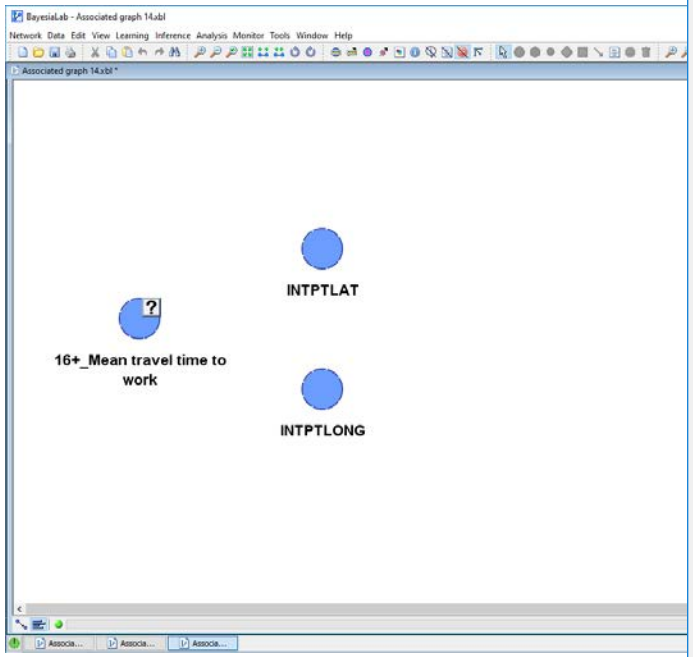


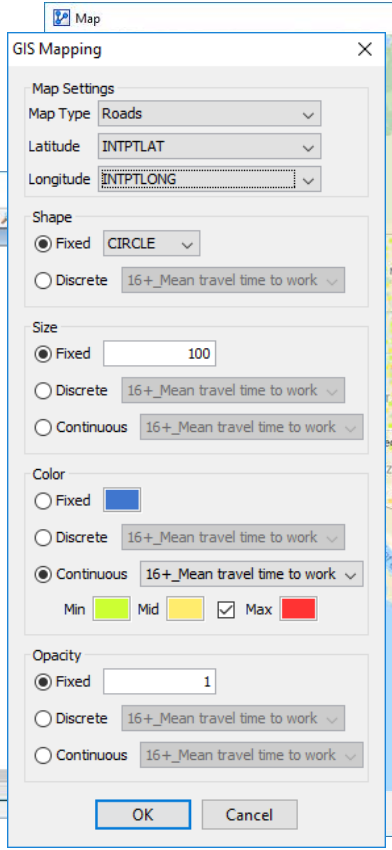
Four attributes can be displayed per observations:

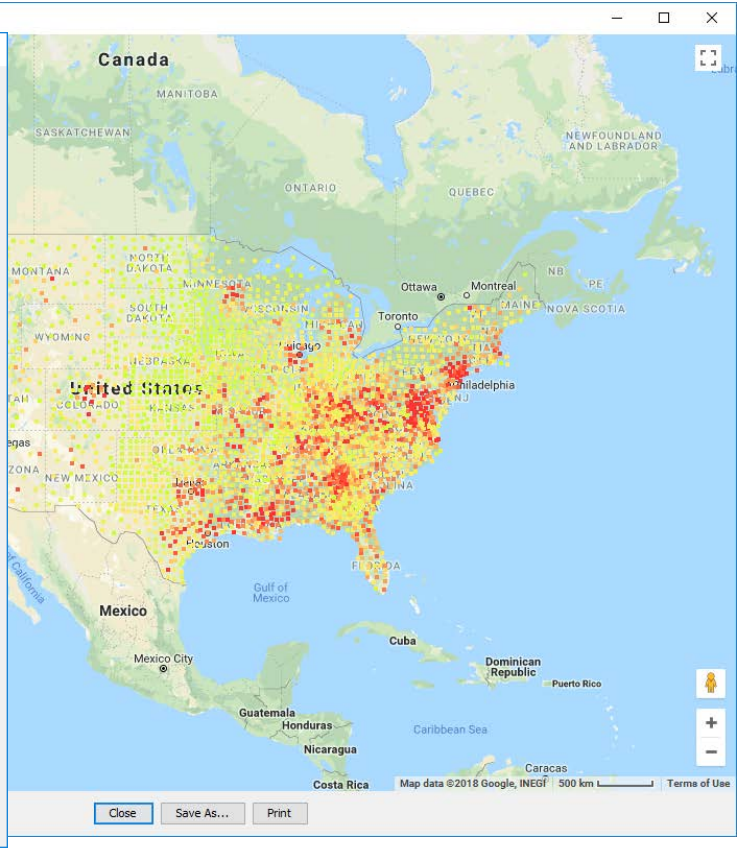
- Shape
- Size
- Color
- Opacity

Example: Mapping Commuting Time

Commuting Time by County







Spatial Learning and Optimization

Bayesian Networks & BayesiaLab

Spatial Learning and Optimization

Optimization Problems Under Consideration

1. One origin, one destination ➔ Shortest Path Problem
2. One origin, many destinations ➔ Drive Time Bands
3. Many origins, one destination ➔ Store Location Problem
4. Many origins, one hub, many destinations ➔ Hub Location Problem
5. Many origins, multiple hubs, many destinations ➔ Multi-Hub Location Problem

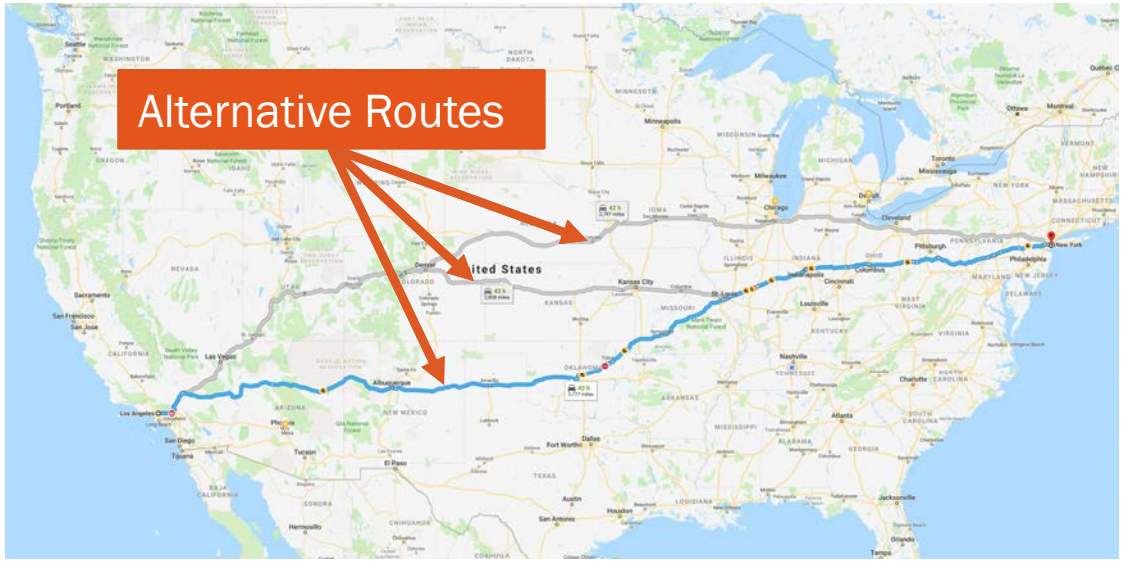
Common Objective

- Minimize “cost function,” e.g., travel time, distance, fuel consumption, number of turns, etc.
- Further assumption: all “participants” have same objective.

Drive Time Bands

Computing the "Cost" for One Origin and One Destination

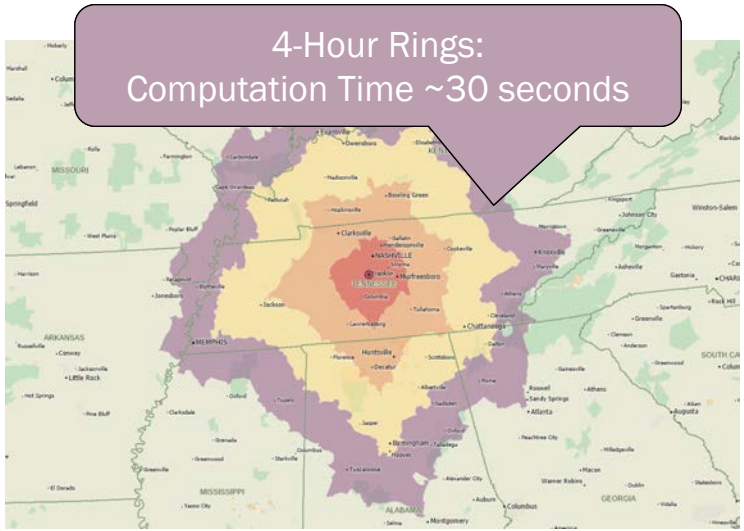
- "Search the Map" ➔ slow, but accurate



Drive Time Bands

Computing the Cost for One Origin and Many Destinations

- "Search the Map" ➔ slow, but accurate



Drive Time Bands

Computing the Cost

- "Search the Map" ➔ slow, but accurate

- Great-Circle Distance Computation

$$d = 2r \arcsin\left(\sqrt{\operatorname{hav}(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\operatorname{hav}(\lambda_2 - \lambda_1)}\right)$$

$$= 2r \arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2)\sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$

- Easy and fast to calculate.
- "As the crow flies" may be an unrealistic assumption.
- Travel time may be more relevant that distance.

Drive Time Bands

Idea: "Create a Look-Up Table for All Origin-Destination Pairs"

- 29,788 ZIP Codes in the U.S.
- A complete distance matrix would contain 887,324,944 cells.
- Current computation speed with Google Distance Matrix API: 2 requests/sec.
- Estimated computation time: ~14 years.

Approximate!

Drive Time Bands

Idea

- Approximation through machine learning.

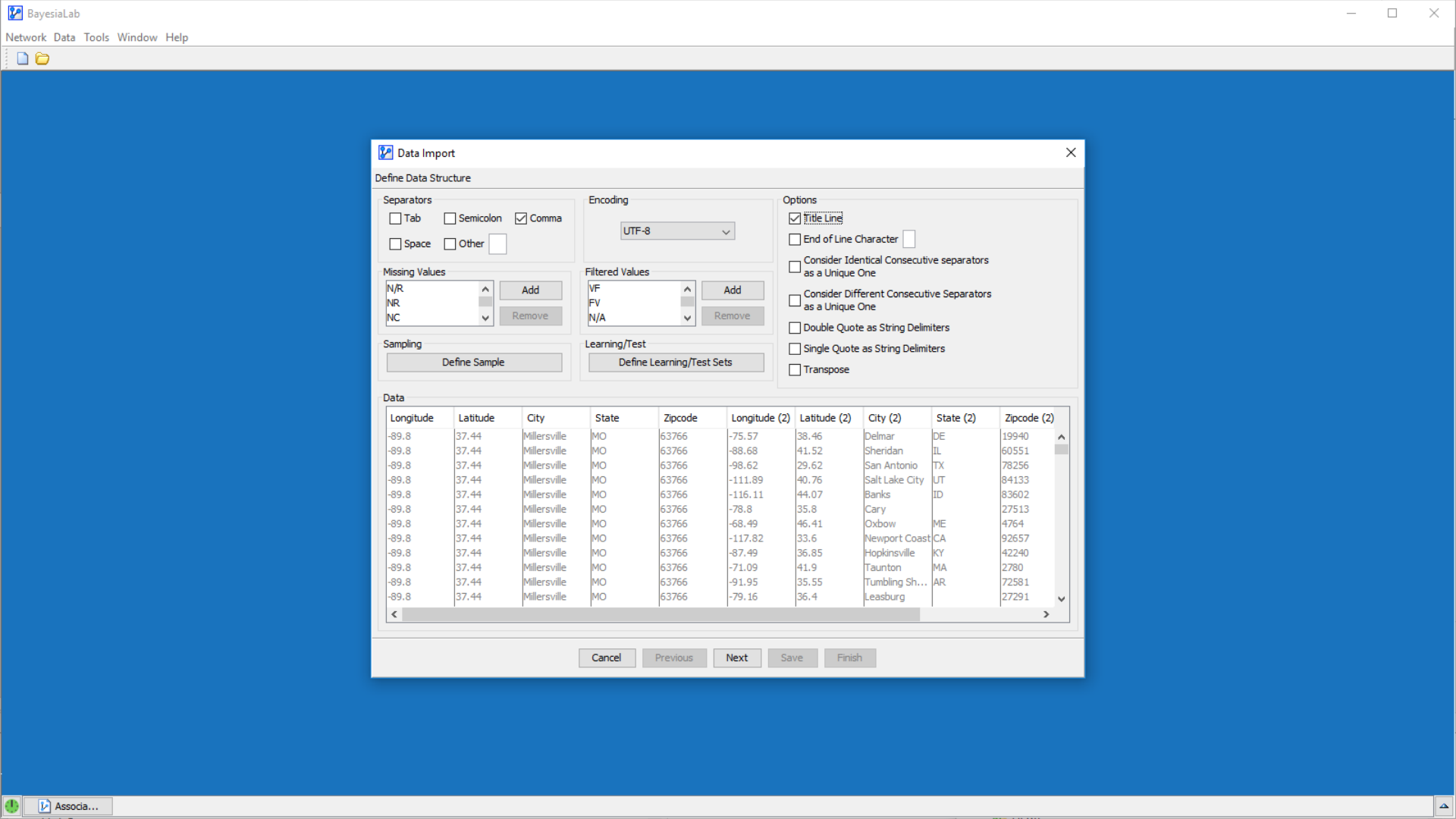
Proposed Approach

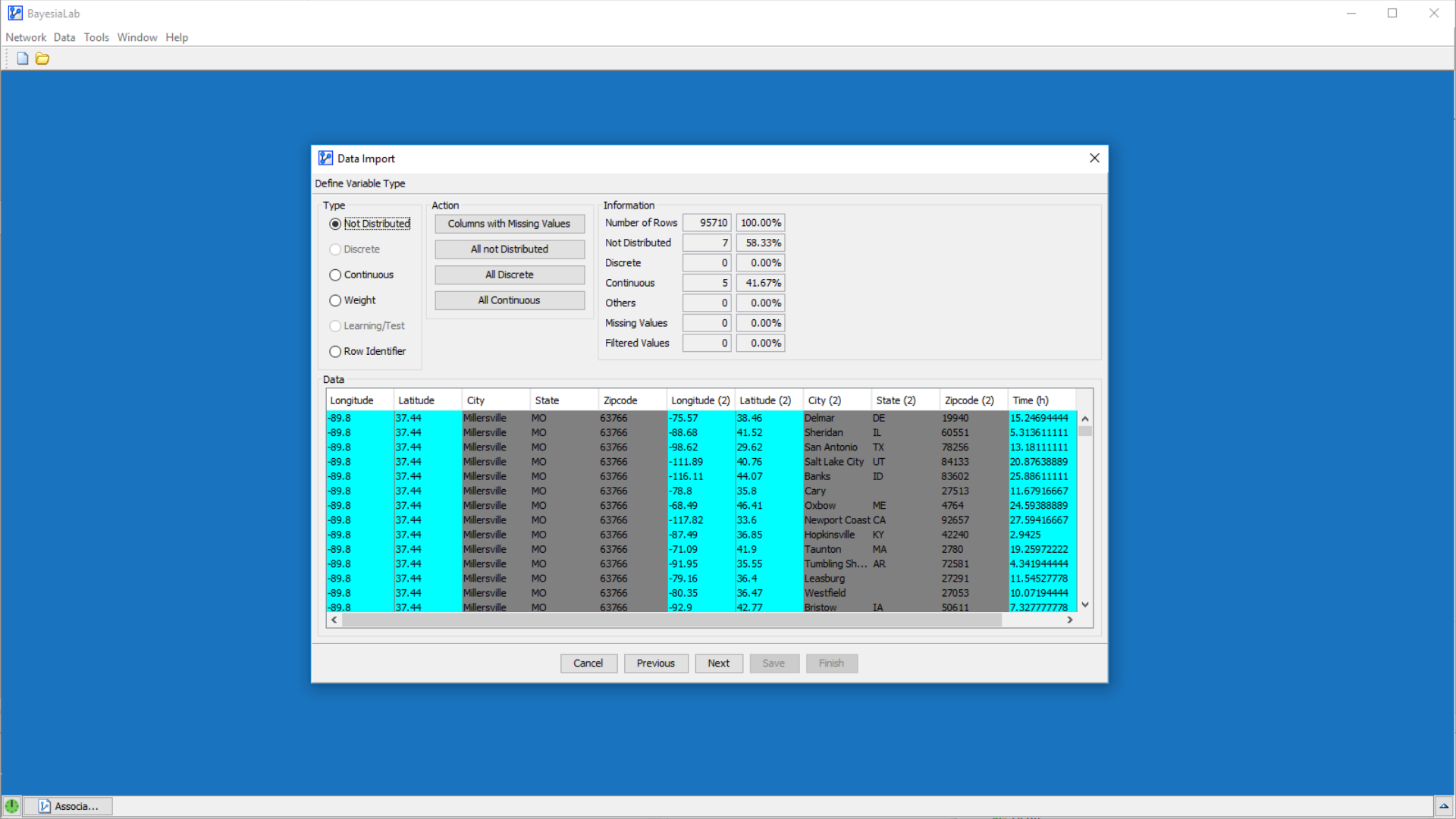
- Utilize database of actual point-to-point travel data.
- Learn a Bayesian network from this dataset.
- Now we can infer the “cost” as a function of origin and destination.

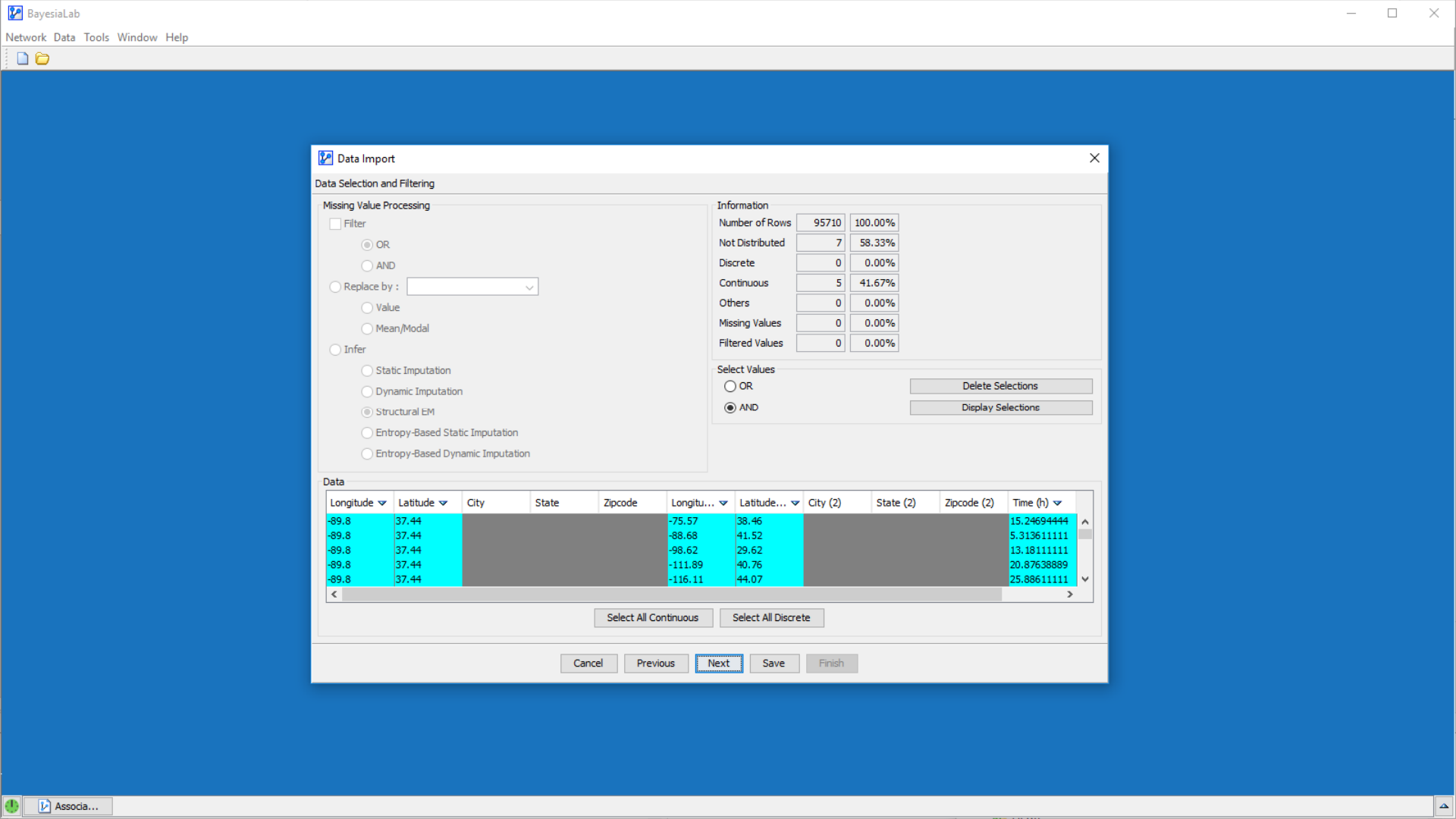
Drive Time Bands

Workflow in Detail

- Take a random sample (~100,000) of origin-destination ZIP code pairs and calculate routes with the Google Distance Matrix API.
- Perform Augmented Naïve Learning.
- Evaluate Target Performance.
- Associate new data set with points to be evaluated.
- Generate map.


BayesiaLab
Network Data Tools Window Help
Data Import
Define Data Structure
Separators
Tab
Semicolon
Comma
Space
Other
Encoding
UTF-8
Options
Title Line
End of Line Character
Consider Identical Consecutive separators as a Unique One
Consider Different Consecutive Separators as a Unique One
Double Quote as String Delimiters
Single Quote as String Delimiters
Transpose
Missing Values
N/R
NR
NC
Add
Remove
Filtered Values
VF
FV
N/A
Add
Remove
Sampling
Define Sample
Learning/Test
Define Learning/Test Sets
Data
Longitude Latitude City State Zipcode Longitude (2) Latitude (2) City (2) State (2) Zipcode (2)
-89.8 37.44 Millersville MO 63766 -75.57 38.46 Delmar DE 19940
-89.8 37.44 Millersville MO 63766 -88.68 41.52 Sheridan IL 60551
-89.8 37.44 Millersville MO 63766 -98.62 29.62 San Antonio TX 78256
-89.8 37.44 Millersville MO 63766 -111.89 40.76 Salt Lake City UT 84133
-89.8 37.44 Millersville MO 63766 -116.11 44.07 Banks ID 83602
-89.8 37.44 Millersville MO 63766 -78.8 35.8 Cary 27513
-89.8 37.44 Millersville MO 63766 -68.49 46.41 Oxbow ME 4764
-89.8 37.44 Millersville MO 63766 -117.82 33.6 Newport Coast CA 92657
-89.8 37.44 Millersville MO 63766 -87.49 36.85 Hopkinsville KY 42240
-89.8 37.44 Millersville MO 63766 -71.09 41.9 Taunton MA 2780
-89.8 37.44 Millersville MO 63766 -91.95 35.55 Tumbling Sh... AR 72581
-89.8 37.44 Millersville MO 63766 -79.16 36.4 Leasburg 27291
Cancel
Previous
Next
Save
Finish
Associa...


BayesiaLab
Network Data Tools Window Help
Data Import
Define Variable Type
Type
Not Distributed
Discrete
Continuous
Weight
Learning/Test
Row Identifier
Action
Columns with Missing Values
All not Distributed
All Discrete
All Continuous
Information
Number of Rows 95710 100.00%
Not Distributed 7 58.33%
Discrete 0 0.00%
Continuous 5 41.67%
Others 0 0.00%
Missing Values 0 0.00%
Filtered Values 0 0.00%
Data
Longitude Latitude City State Zipcode Longitude (2) Latitude (2) City (2) State (2) Zipcode (2) Time (h)
-89.8 37.44 Millersville MO 63766 -75.57 38.46 Delmar DE 19940 15.24694444
-89.8 37.44 Millersville MO 63766 -88.68 41.52 Sheridan IL 60551 5.313611111
-89.8 37.44 Millersville MO 63766 -98.62 29.62 San Antonio TX 78256 13.18111111
-89.8 37.44 Millersville MO 63766 -111.89 40.76 Salt Lake City UT 84133 20.87638889
-89.8 37.44 Millersville MO 63766 -116.11 44.07 Banks ID 83602 25.88611111
-89.8 37.44 Millersville MO 63766 -78.8 35.8 Cary 27513 11.67916667
-89.8 37.44 Millersville MO 63766 -68.49 46.41 Oxbow ME 4764 24.59388889
-89.8 37.44 Millersville MO 63766 -117.82 33.6 Newport Coast CA 92657 27.59416667
-89.8 37.44 Millersville MO 63766 -87.49 36.85 Hopkinsville KY 42240 2.9425
-89.8 37.44 Millersville MO 63766 -71.09 41.9 Taunton MA 2780 19.25972222
-89.8 37.44 Millersville MO 63766 -91.95 35.55 Tumbling Sh... AR 72581 4.341944444
-89.8 37.44 Millersville MO 63766 -79.16 36.4 Leasburg 27291 11.54527778
-89.8 37.44 Millersville MO 63766 -80.35 36.47 Westfield 27053 10.07194444
-89.8 37.44 Millersville MO 63766 -92.9 42.77 Bristow IA 50611 7.327777778
Cancel
Previous
Next
Save
Finish
Associa...


BayesiaLab
Network Data Tools Window Help
Data Import
Data Selection and Filtering
Missing Value Processing
Filter
OR
AND
Replace by :
Value
Mean/Modal
Infer
Static Imputation
Dynamic Imputation
Structural EM
Entropy-Based Static Imputation
Entropy-Based Dynamic Imputation
Information
Number of Rows 95710 100.00%
Not Distributed 7 58.33%
Discrete 0 0.00%
Continuous 5 41.67%
Others 0 0.00%
Missing Values 0 0.00%
Filtered Values 0 0.00%
Select Values
OR
AND
Delete Selections
Display Selections
Data
Longitude Latitude City State Zipcode Longitu... Latitude... City (2) State (2) Zipcode (2) Time (h)
-89.8 37.44 -75.57 38.46 15.24694444
-89.8 37.44 -88.68 41.52 5.313611111
-89.8 37.44 -98.62 29.62 13.18111111
-89.8 37.44 -111.89 40.76 20.87638889
-89.8 37.44 -116.11 44.07 25.88611111
Select All Continuous
Select All Discrete
Cancel
Previous
Next
Save
Finish
Associa...

BayesiaLab

Network Data Tools Window Help

Data Import

Discretization and Aggregation

Discretization

Type: Manual

Maximum:

Minimum:

Threshold Value: 32

Previous Next

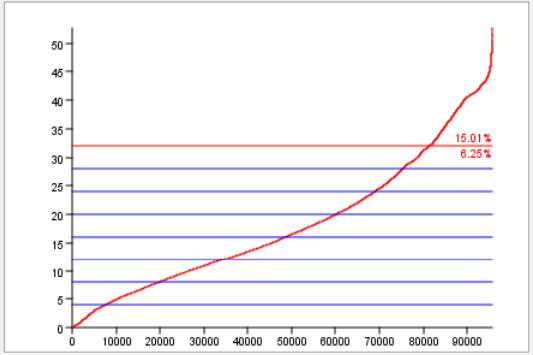
Density Function

Generate a Discretization

Transfer the Discretization Thresholds

Create a class for each type of discretization

Load Discretizations



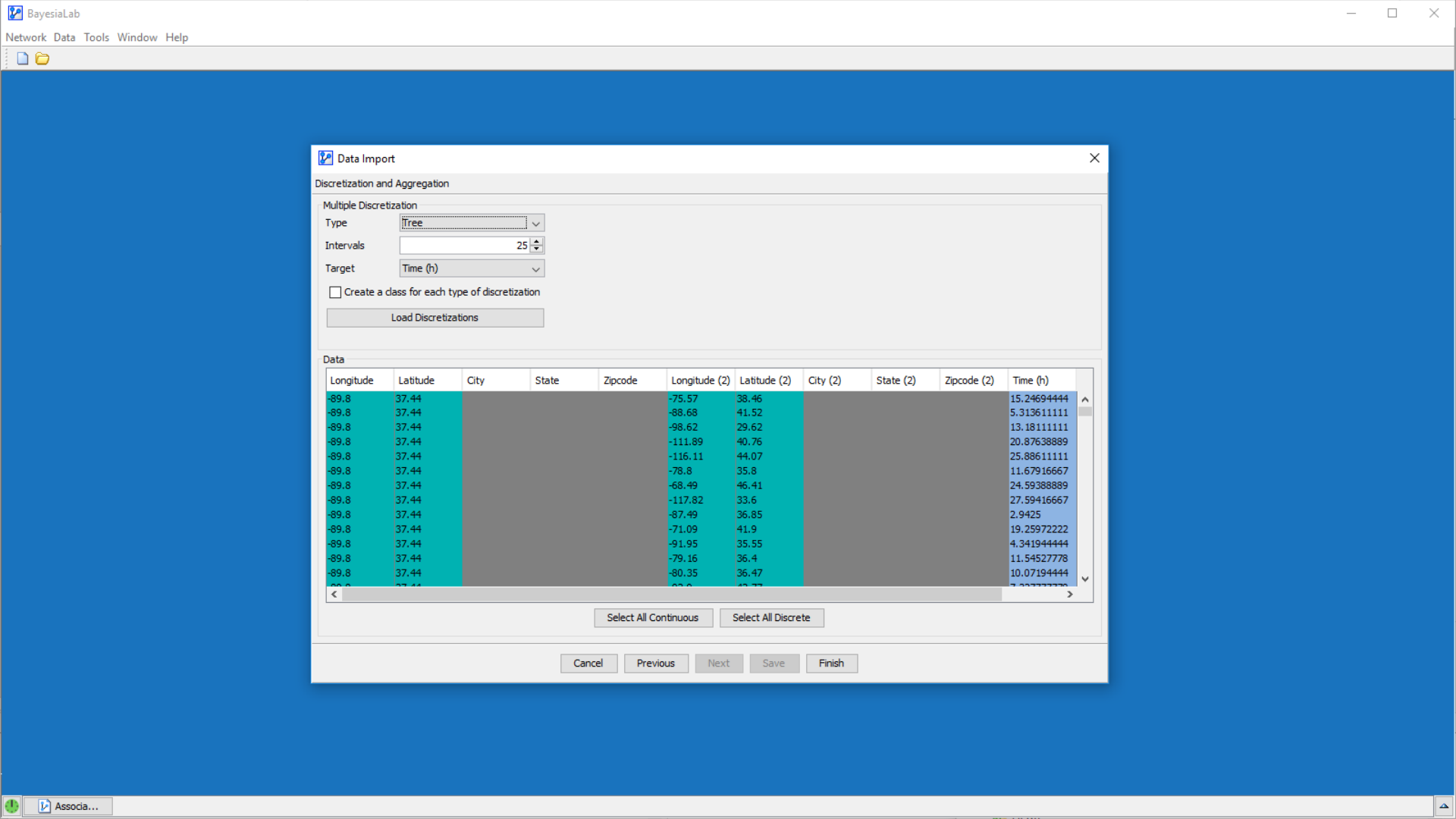
Data

Longitude	Latitude	City	State	Zipcode	Longitude (2)	Latitude (2)	City (2)	State (2)	Zipcode (2)	Time (h)
-89.8	37.44				-75.57	38.46				15.24694444
-89.8	37.44				-88.68	41.52				5.313611111
-89.8	37.44				-98.62	29.62				13.18111111
-89.8	37.44				-111.89	40.76				20.87638889

Select All Continuous Select All Discrete

Cancel Previous Next Save Finish

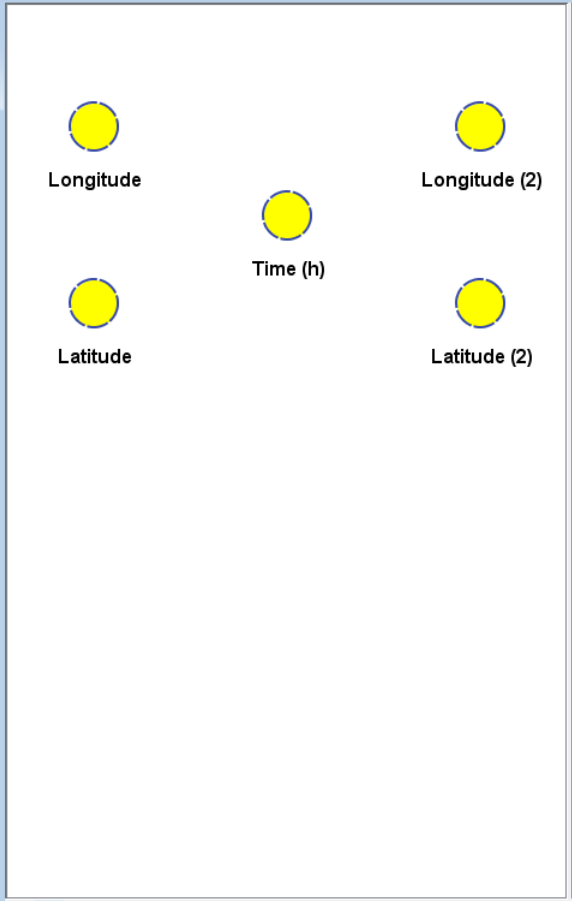
Associa...


BayesiaLab
Network Data Tools Window Help
Data Import
Discretization and Aggregation
Multiple Discretization
Type
Tree
Intervals
25
Target
Time (h)
Create a class for each type of discretization
Load Discretizations
Data
Longitude Latitude City State Zipcode Longitude (2) Latitude (2) City (2) State (2) Zipcode (2) Time (h)
-89.8 37.44 -75.57 38.46 15.24694444
-89.8 37.44 -88.68 41.52 5.313611111
-89.8 37.44 -98.62 29.62 13.18111111
-89.8 37.44 -111.89 40.76 20.87638889
-89.8 37.44 -116.11 44.07 25.88611111
-89.8 37.44 -78.8 35.8 11.67916667
-89.8 37.44 -68.49 46.41 24.59388889
-89.8 37.44 -117.82 33.6 27.59416667
-89.8 37.44 -87.49 36.85 2.9425
-89.8 37.44 -71.09 41.9 19.25972222
-89.8 37.44 -91.95 35.55 4.341944444
-89.8 37.44 -79.16 36.4 11.54527778
-89.8 37.44 -80.35 36.47 10.07194444
Select All Continuous
Select All Discrete
Cancel
Previous
Next
Save
Finish

BayesiaLab - Associated graph 5.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 5.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Cases: 95,710
Total Value: -89.271
Mean Value: -17.854

Time (h)
Mean: 18.133 Dev: 11.532
Value: 18.133

7.99%	<=4
12.80%	<=8
15.18%	<=12
14.65%	<=16
12.07%	<=20
9.36%	<=24
6.68%	<=28
6.25%	<=32
15.01%	>32

Latitude
Mean: 38.133 Dev: 4.636
Value: 38.133

1.89%	<=27.31
0.88%	<=28.98
4.87%	<=31.14
3.08%	<=32.46
1.19%	<=32.735
2.47%	<=33.31
1.09%	<=33.495
8.42%	<=34.255
7.74%	<=35.95
32.15%	<=40.445
0.35%	<=40.495
0.95%	<=40.59
6.91%	<=40.895
3.88%	<=41.395
2.51%	<=41.71
3.69%	<=42.065
6.38%	<=43.07
2.44%	<=43.94
2.99%	<=44.99
1.25%	<=45.555
0.91%	<=46.095
0.35%	<=46.285
1.73%	<=47.29
0.38%	<=47.42
1.49%	>47.42

Longitude (2)
Mean: -91.911 Dev: 15.538
Value: -91.911

2.20%	<=-122.475
1.29%	<=-122.095
2.42%	<=-121.285
1.16%	<=-119.675
7.33%	<=-116.945
1.30%	<=-115.215
0.50%	<=-114.595
2.91%	<=-110.135
2.40%	<=-105.275
1.26%	<=-103.095
6.01%	<=-97.41
4.95%	<=-95.765
1.68%	<=-95.34
5.38%	<=-92.185
11.16%	<=-87.545
9.48%	<=-84.155
0.80%	<=-83.98
0.70%	<=-80.025
1.09%	<=-80.445
2.25%	<=-80.06
14.14%	<=-74.315
4.83%	<=-73.865
2.02%	<=-73.22
3.70%	<=-69.87
0.95%	>-69.87

Latitude (2)
Mean: 38.136 Dev: 4.629
Value: 38.136

2.64%	<=28.545
4.84%	<=31.14
3.05%	<=32.51
1.62%	<=32.81
2.34%	<=33.41
0.74%	<=33.495
8.71%	<=34.255
7.78%	<=35.925
4.23%	<=36.59
2.29%	<=36.845
2.43%	<=37.275
0.56%	<=37.425
7.97%	<=38.695
16.01%	<=40.59
6.27%	<=40.875
1.68%	<=41.045
0.26%	<=41.065
4.95%	<=41.71
3.49%	<=42.065
6.86%	<=43.155
4.69%	<=44.955
6.59%	>44.955

Longitude
Mean: -91.761 Dev: 15.505
Value: -91.761

2.05%	<=-122.475
4.19%	<=-121.01
0.79%	<=-119.68
7.38%	<=-116.87
0.85%	<=-115.665
1.07%	<=-112.175
2.55%	<=-110.135
2.13%	<=-105.675
2.40%	<=-101.98
9.38%	<=-95.845
1.32%	<=-95.51
0.69%	<=-95.34
6.89%	<=-91.705
6.89%	<=-88.3
2.70%	<=-87.665
1.21%	<=-87.325
6.17%	<=-84.755
4.61%	<=-83.675
8.38%	<=-80.445
2.08%	<=-80.1
14.63%	<=-74.22
4.63%	<=-73.865
2.13%	<=-73.22
3.91%	<=-69.87
0.94%	>-69.87

0:0

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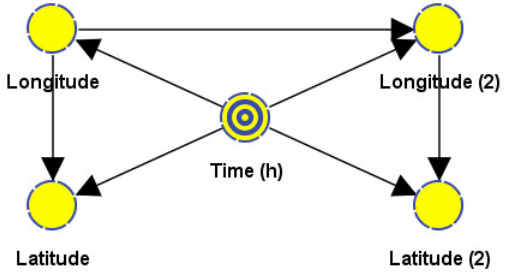
Associa...

BayesiaLab - Associated graph 5.xbl

Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Associated graph 5.xbl *



Joint Probability: 100.00%
Log-Loss: 0
Cases: 95,710
Total Value: -89.271
Mean Value: -17.854

Time (h)
Mean: 18.133 Dev: 11.532
Value: 18.133

7.99%	<=4
12.80%	<=8
15.18%	<=12
14.65%	<=16
12.07%	<=20
9.36%	<=24
6.68%	<=28
6.25%	<=32
15.01%	>32

Longitude
Mean: -91.762 Dev: 15.505
Value: -91.762

2.05%	<=-122.475
4.19%	<=-121.01
0.79%	<=-119.68
7.38%	<=-116.87
0.85%	<=-115.665
1.07%	<=-112.175
2.55%	<=-110.135
2.13%	<=-105.675
2.40%	<=-101.98
9.38%	<=-95.845
1.32%	<=-95.51
0.69%	<=-95.34
6.89%	<=-91.705
6.89%	<=-88.3
2.70%	<=-87.665
1.21%	<=-87.325
6.17%	<=-84.755
4.61%	<=-83.675
8.38%	<=-80.445
2.08%	<=-80.1
14.63%	<=-74.22
4.63%	<=-73.865
2.13%	<=-73.22
3.91%	<=-69.87
0.94%	>-69.87

Latitude (2)
Mean: 38.136 Dev: 4.629
Value: 38.136

%	<=28.545
%	<=31.14
%	<=32.51
%	<=32.81
%	<=33.41
%	<=33.495
%	<=34.255
%	<=35.925
%	<=36.59
%	<=36.845
%	<=37.275
%	<=37.425
%	<=38.695
%	<=40.59
%	<=40.875
%	<=41.045
%	<=41.065
%	<=41.71
%	<=42.065
%	<=43.155
%	<=44.955
%	>44.955

Target Evaluation of Time (h)

Overall Precision: 65.0601%
Mean Precision: 64.6153%
Overall Reliability: 65.5115%
Mean Reliability: 65.6798%
Overall Relative Gini Index: 89.2850%
Mean Relative Gini Index: 90.2438%
Overall Relative Lift Index: 87.5530%
Mean Relative Lift Index: 88.1161%
Overall ROC Index: 94.6425%
Mean ROC Index: 95.1219%
Overall Calibration Index: 95.4363%
Mean Calibration Index: 95.4809%
Overall Log-Loss: 0.8014
Mean Binary Log-Loss: 0.1538
R: 0.9699
RMSE: 2.8221
R2: 0.9407
NRMSE: 5.3598%

Comprehensive Report

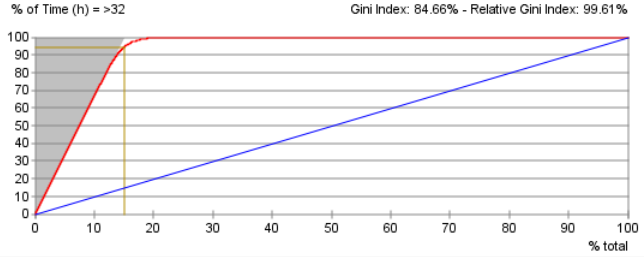
Confusion Matrix

Occurrences | Reliability | Precision

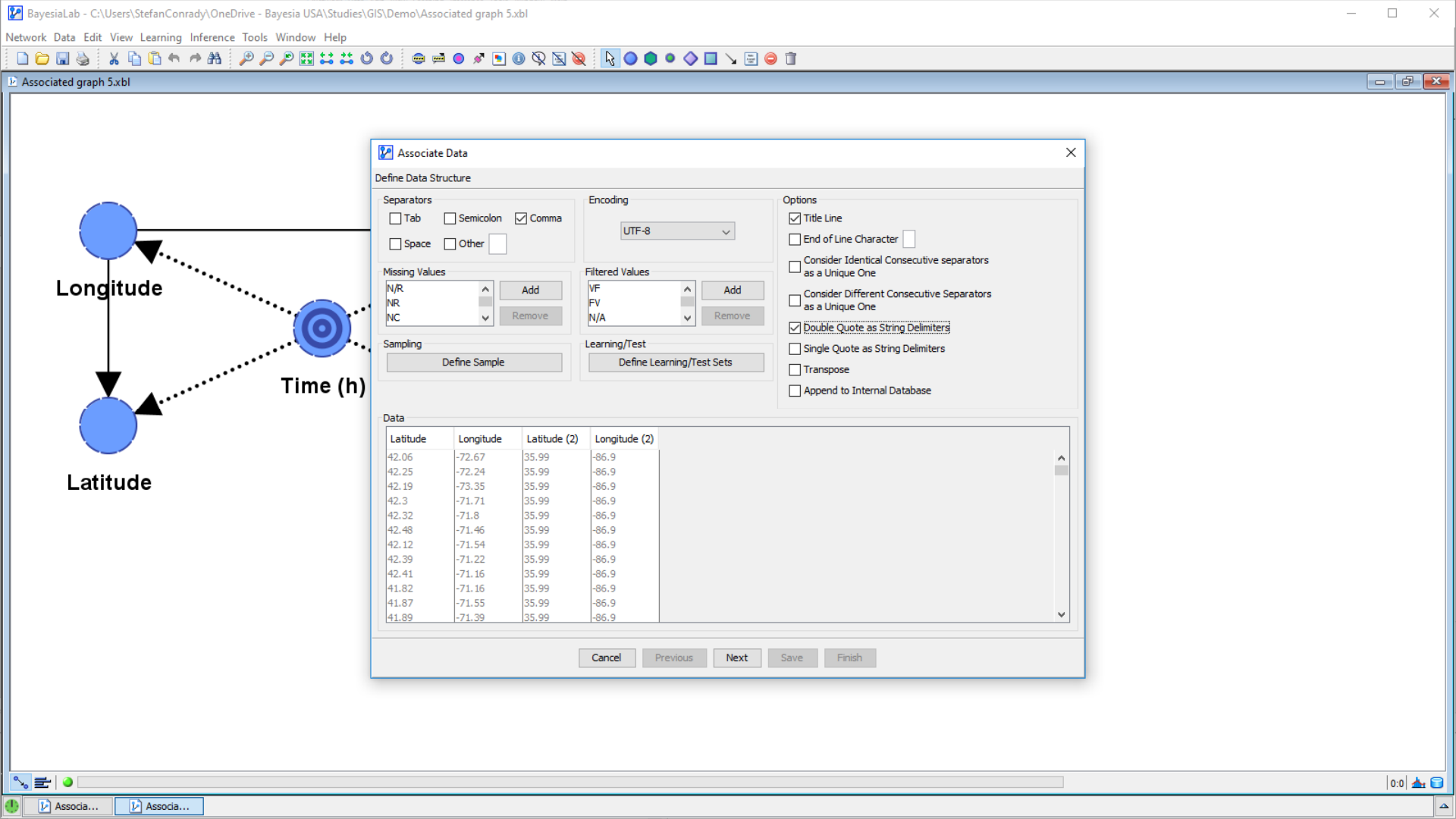
Value	<=4 (7648)	<=8 (12254)	<=12 (14528)	<=16 (14024)	<
<=4 (7077)	4846	1525	376	167	
<=8 (15147)	2463	8134	3370	979	
<=12 (15069)	233	2294	8371	3326	
<=16 (13525)	60	223	2201	7736	
<=20 (10240)	46	74	194	1732	
<=24 (9154)	0	4	14	78	
<=28 (5812)	0	0	2	6	
<=32 (5718)	0	0	0	0	

<=4 | <=8 | <=12 | <=16 | <=20 | <=24 | <=28 | <=32 | >32

Gains Curve | Lift Curve | ROC Curve | Calibration Curve



Options


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 5.xbl
Longitude
Time (h)
Latitude
Associate Data
Define Data Structure
Separators
Tab
Semicolon
Comma
Space
Other
Encoding
UTF-8
Options
Title Line
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Consider Identical Consecutive separators as a Unique One
Consider Different Consecutive Separators as a Unique One
Double Quote as String Delimiters
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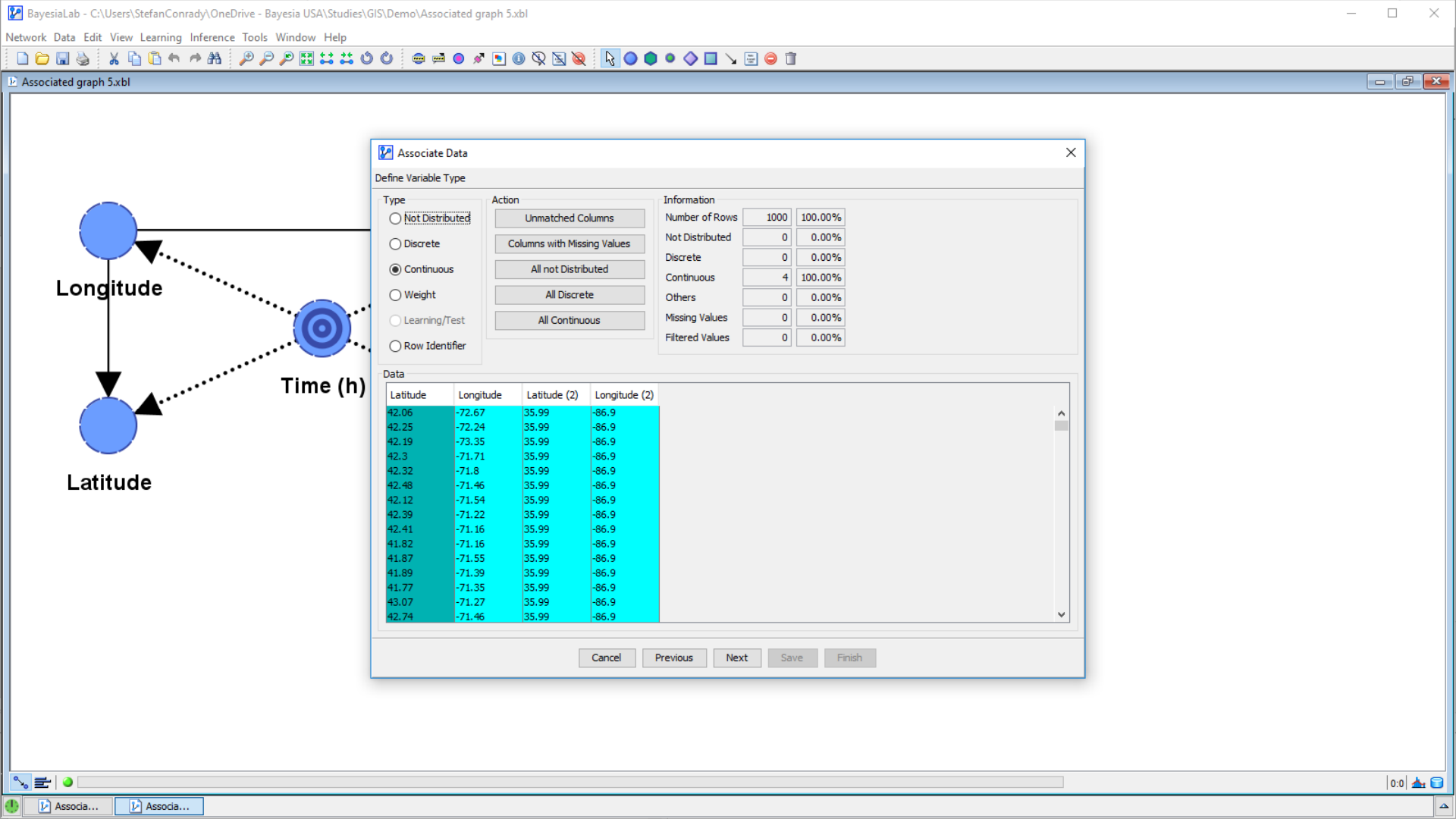
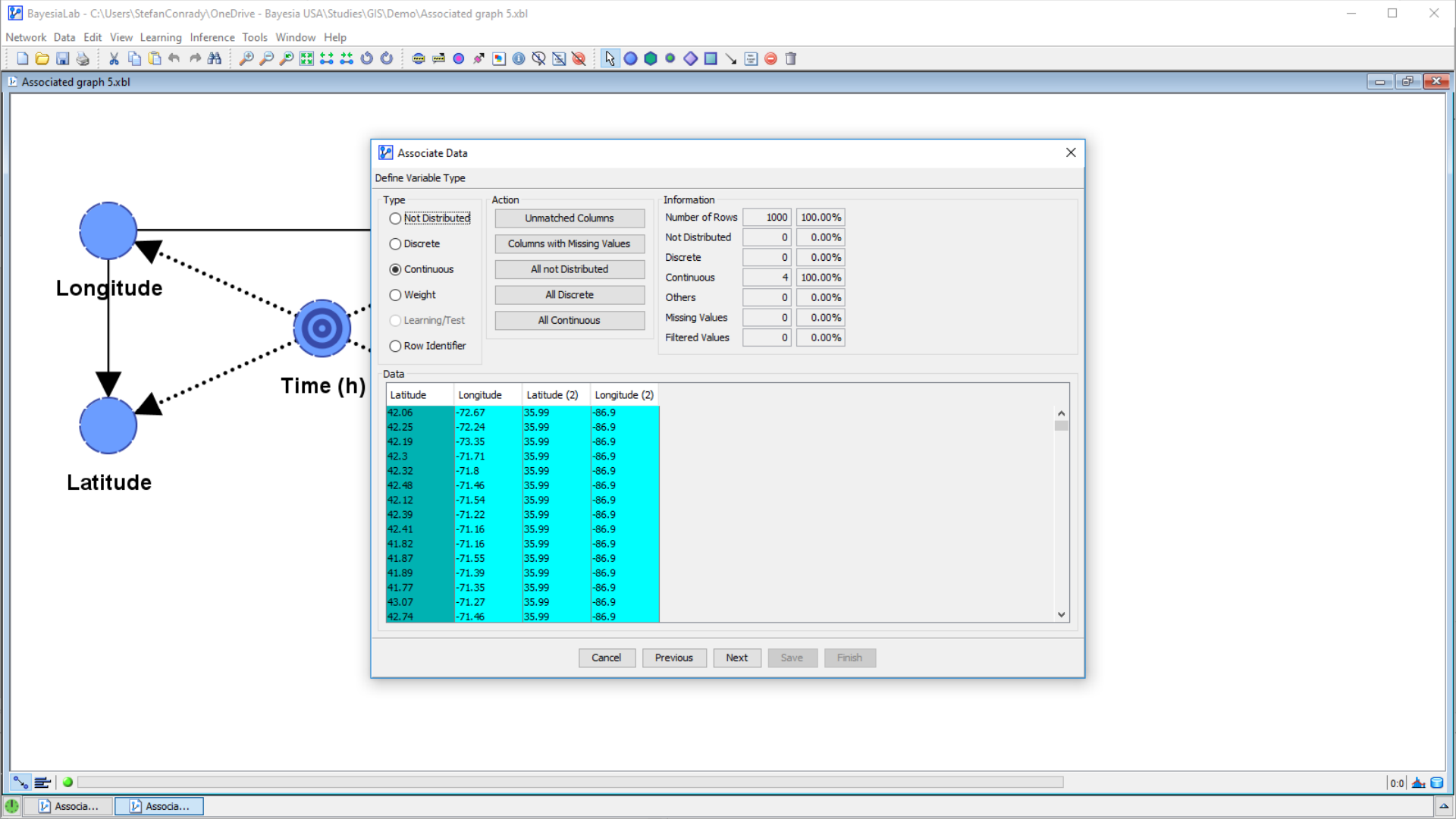
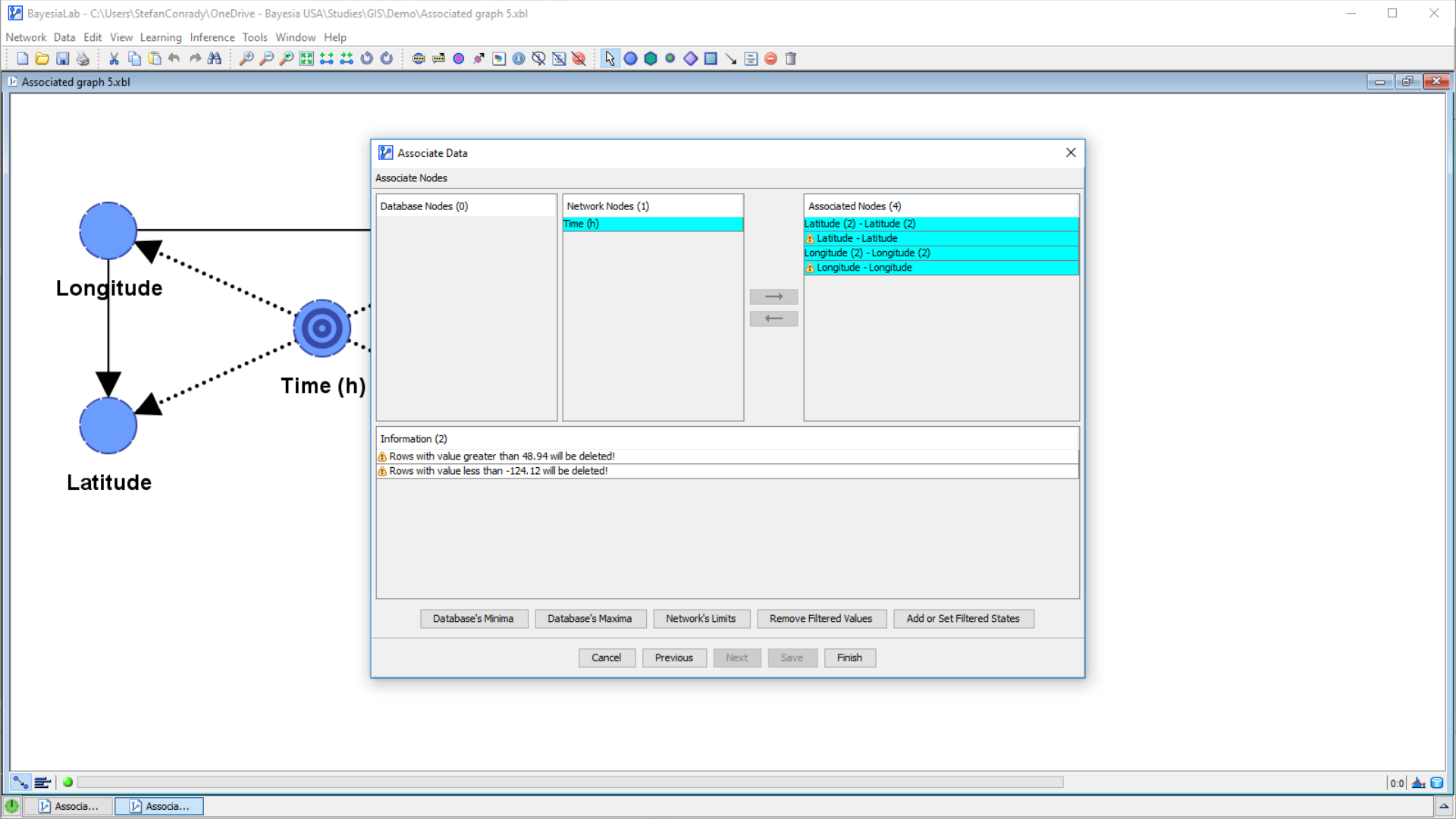
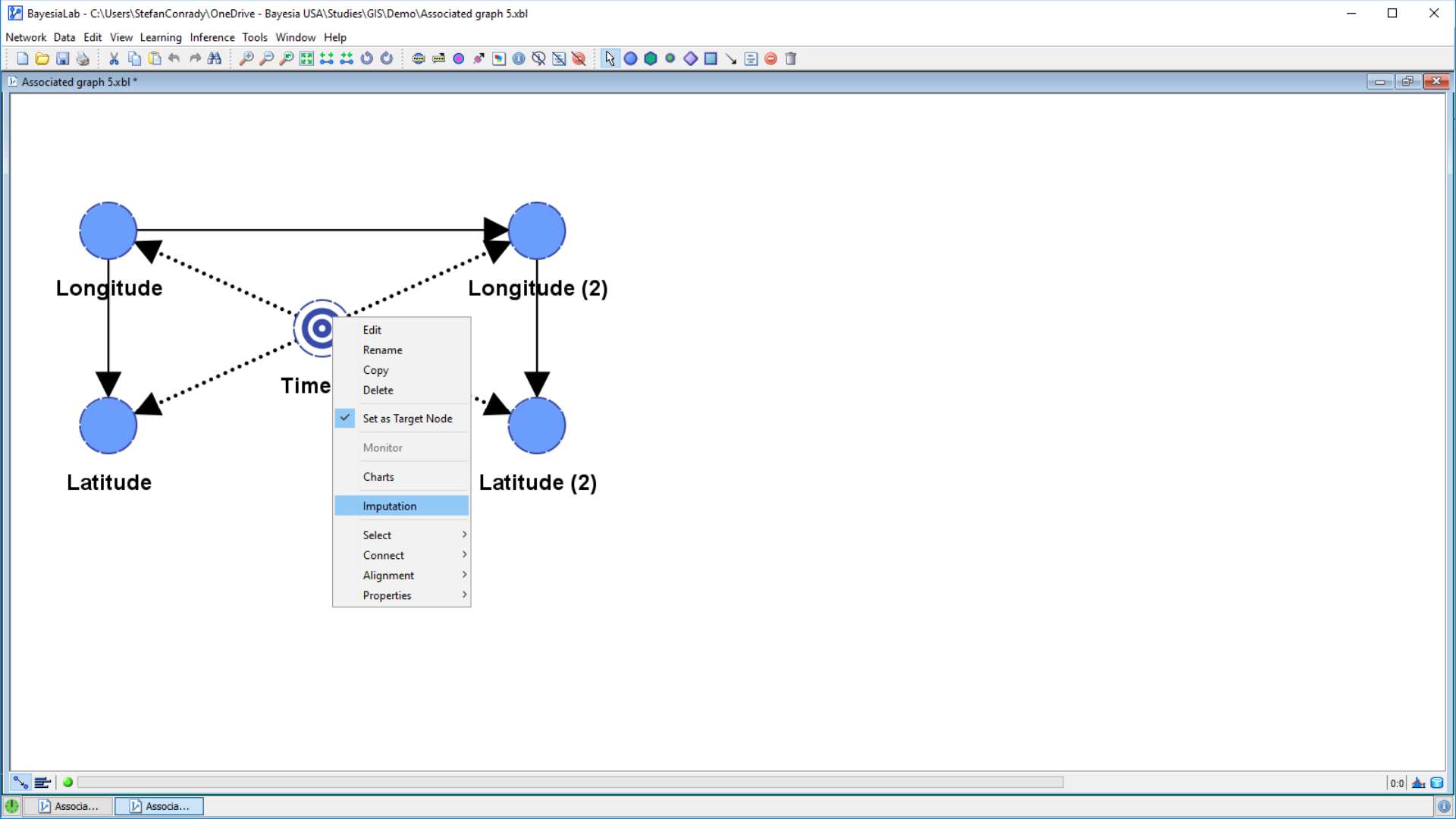
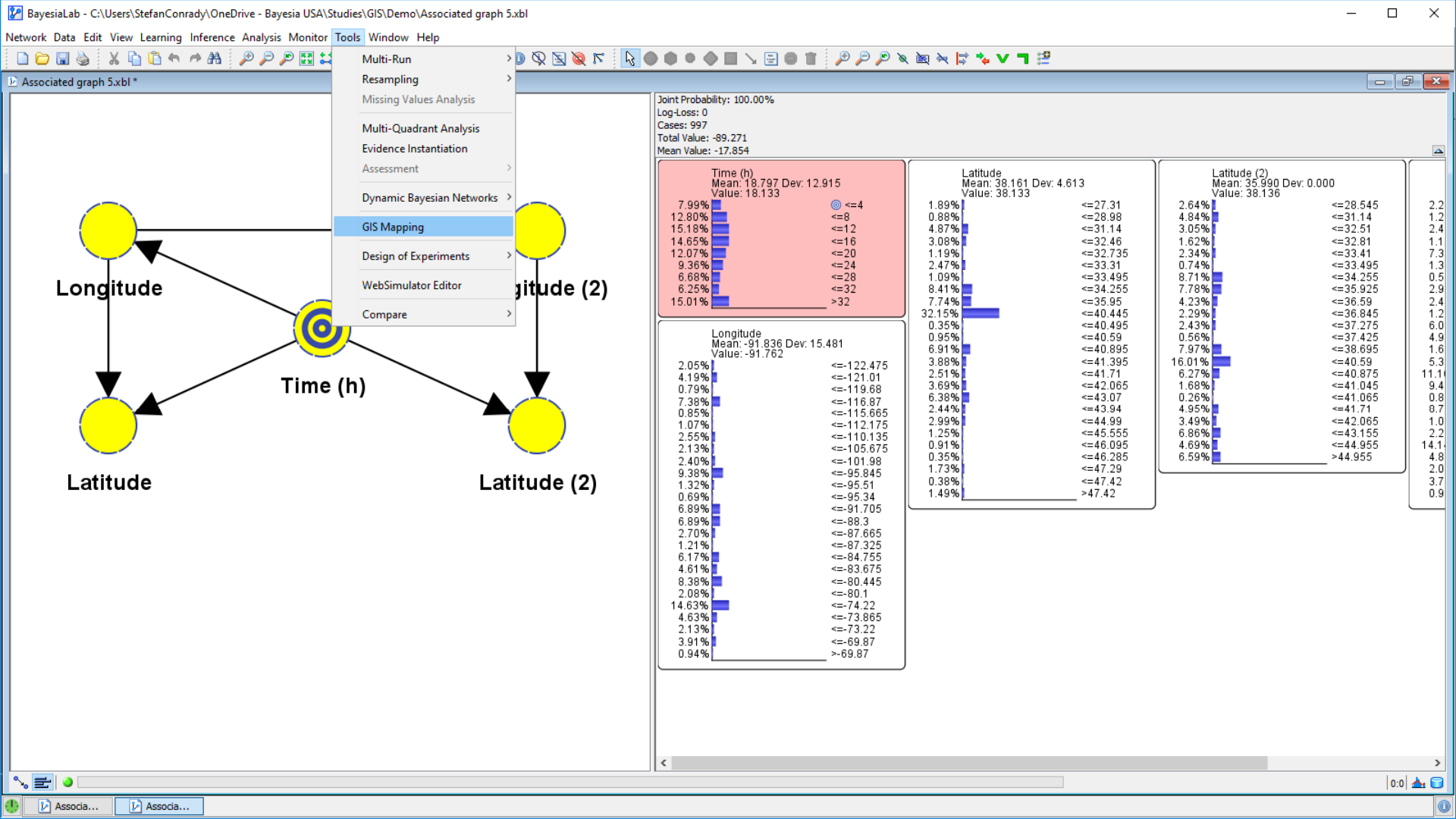
Transpose
Append to Internal Database
Missing Values
N/R
NR
NC
Add
Remove
Filtered Values
VF
FV
N/A
Add
Remove
Sampling
Define Sample
Learning/Test
Define Learning/Test Sets
Data
Latitude
Longitude
Latitude (2)
Longitude (2)
42.06 -72.67 35.99 -86.9
42.25 -72.24 35.99 -86.9
42.19 -73.35 35.99 -86.9
42.3 -71.71 35.99 -86.9
42.32 -71.8 35.99 -86.9
42.48 -71.46 35.99 -86.9
42.12 -71.54 35.99 -86.9
42.39 -71.22 35.99 -86.9
42.41 -71.16 35.99 -86.9
41.82 -71.16 35.99 -86.9
41.87 -71.55 35.99 -86.9
41.89 -71.39 35.99 -86.9
Cancel
Previous
Next
Save
Finish

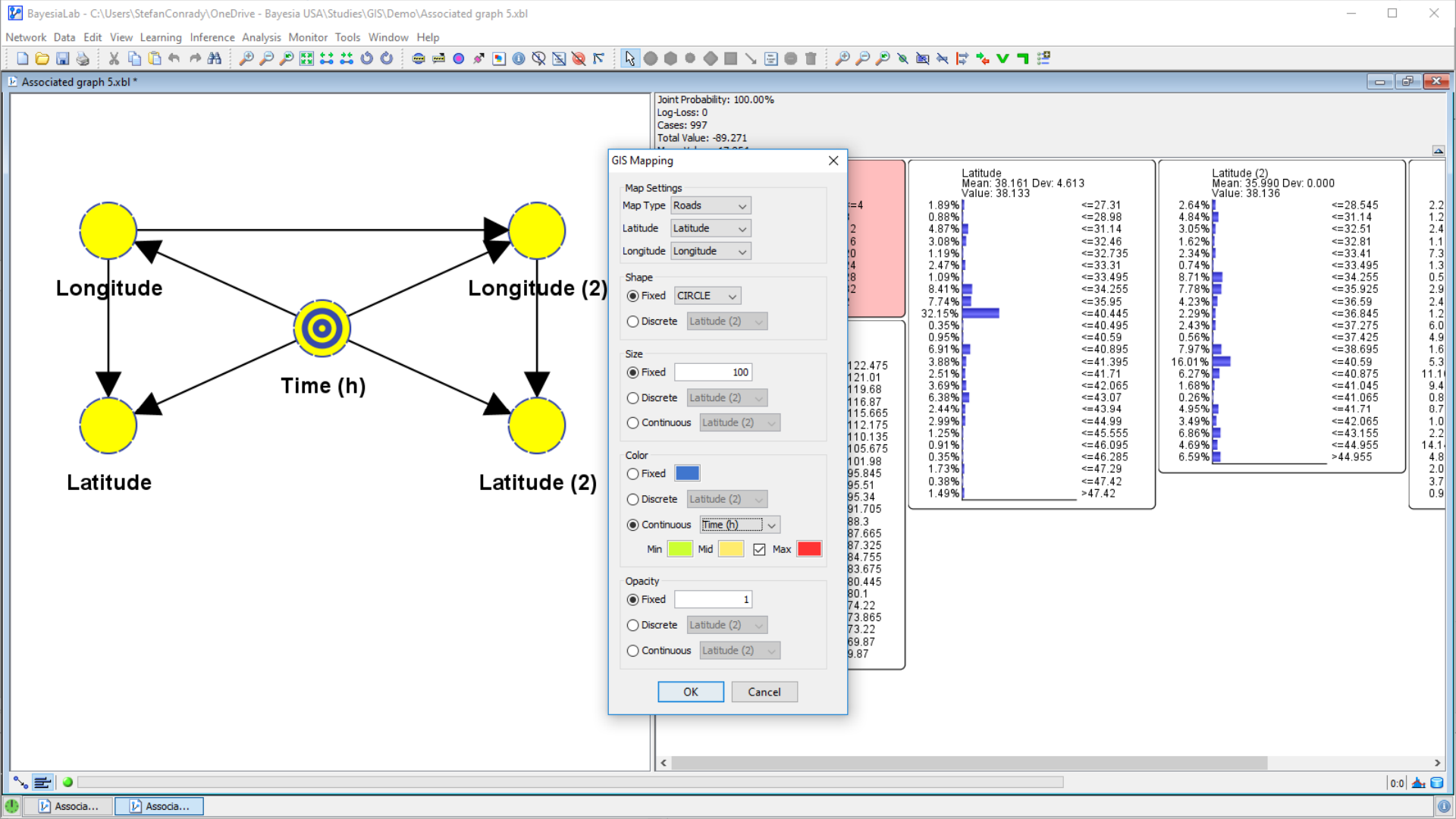

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 5.xbl
Longitude
Time (h)
Latitude
Associate Data
Define Variable Type
Type
Not Distributed
Discrete
Continuous
Weight
Learning/Test
Row Identifier
Action
Unmatched Columns
Columns with Missing Values
All not Distributed
All Discrete
All Continuous
Information
Number of Rows 1000 100.00%
Not Distributed 0 0.00%
Discrete 0 0.00%
Continuous 4 100.00%
Others 0 0.00%
Missing Values 0 0.00%
Filtered Values 0 0.00%
Data
Latitude Longitude Latitude (2) Longitude (2)
42.06 -72.67 35.99 -86.9
42.25 -72.24 35.99 -86.9
42.19 -73.35 35.99 -86.9
42.3 -71.71 35.99 -86.9
42.32 -71.8 35.99 -86.9
42.48 -71.46 35.99 -86.9
42.12 -71.54 35.99 -86.9
42.39 -71.22 35.99 -86.9
42.41 -71.16 35.99 -86.9
41.82 -71.16 35.99 -86.9
41.87 -71.55 35.99 -86.9
41.89 -71.39 35.99 -86.9
41.77 -71.35 35.99 -86.9
43.07 -71.27 35.99 -86.9
42.74 -71.46 35.99 -86.9
Cancel
Previous
Next
Save
Finish

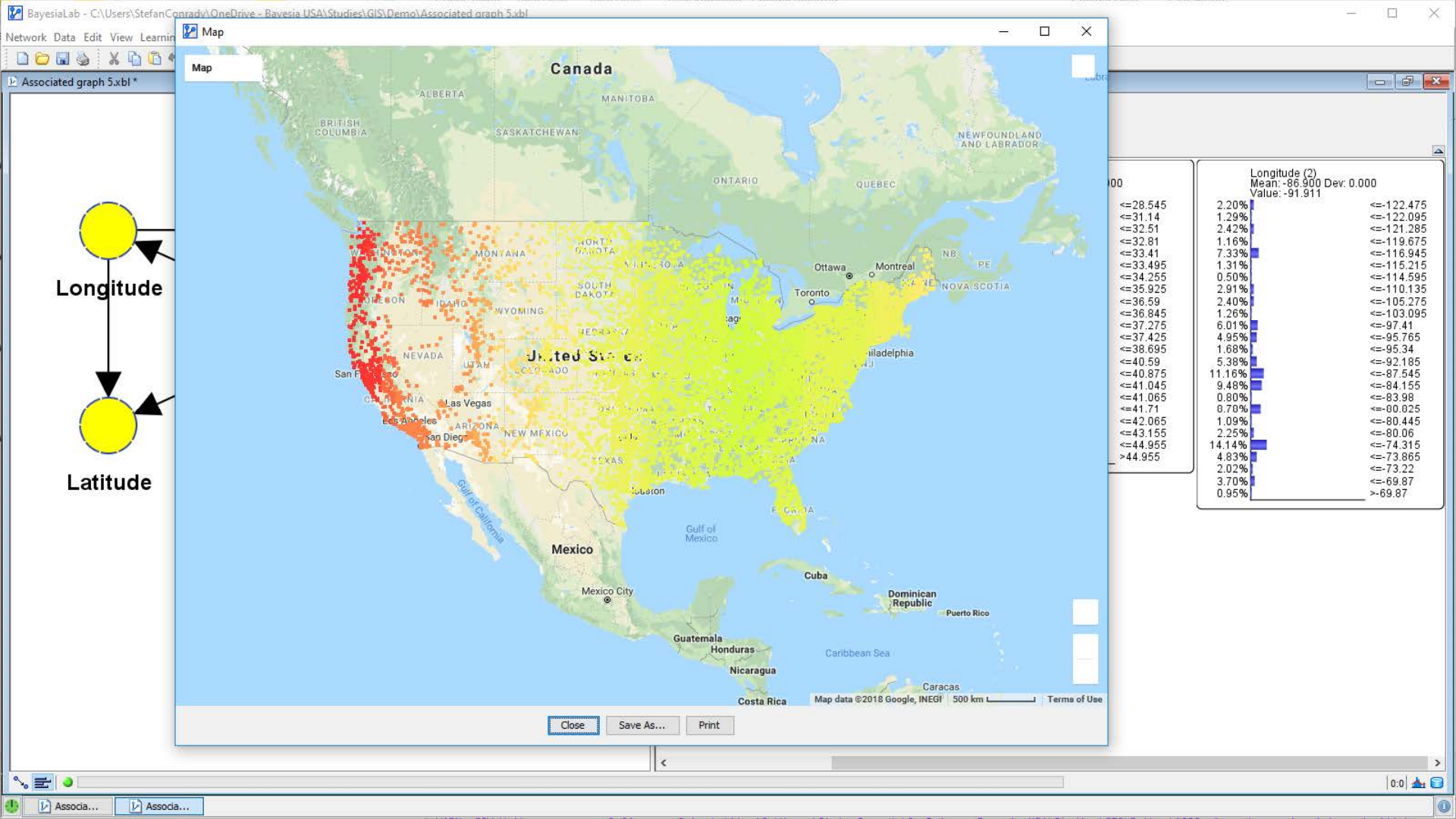

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 5.xbl
Longitude
Time (h)
Latitude
Associate Data
Define Variable Type
Type
Not Distributed
Discrete
Continuous
Weight
Learning/Test
Row Identifier
Action
Unmatched Columns
Columns with Missing Values
All not Distributed
All Discrete
All Continuous
Information
Number of Rows 1000 100.00%
Not Distributed 0 0.00%
Discrete 0 0.00%
Continuous 4 100.00%
Others 0 0.00%
Missing Values 0 0.00%
Filtered Values 0 0.00%
Data
Latitude Longitude Latitude (2) Longitude (2)
42.06 -72.67 35.99 -86.9
42.25 -72.24 35.99 -86.9
42.19 -73.35 35.99 -86.9
42.3 -71.71 35.99 -86.9
42.32 -71.8 35.99 -86.9
42.48 -71.46 35.99 -86.9
42.12 -71.54 35.99 -86.9
42.39 -71.22 35.99 -86.9
42.41 -71.16 35.99 -86.9
41.82 -71.16 35.99 -86.9
41.87 -71.55 35.99 -86.9
41.89 -71.39 35.99 -86.9
41.77 -71.35 35.99 -86.9
43.07 -71.27 35.99 -86.9
42.74 -71.46 35.99 -86.9
Cancel
Previous
Next
Save
Finish


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 5.xbl
Longitude
Time (h)
Latitude
Associate Data
Associate Nodes
Database Nodes (0)
Network Nodes (1)
Time (h)
Associated Nodes (4)
Latitude (2) - Latitude (2)
Latitude - Latitude
Longitude (2) - Longitude (2)
Longitude - Longitude
Information (2)
Rows with value greater than 48.94 will be deleted!
Rows with value less than -124.12 will be deleted!
Database's Minima
Database's Maxima
Network's Limits
Remove Filtered Values
Add or Set Filtered States
Cancel
Previous
Next
Save
Finish


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Tools Window Help
Associated graph 5.xbl *
Longitude
Longitude (2)
Time
Latitude
Latitude (2)
Edit
Rename
Copy
Delete
Set as Target Node
Monitor
Charts
Imputation
Select
Connect
Alignment
Properties


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Multi-Run
Resampling
Missing Values Analysis
Multi-Quadrant Analysis
Evidence Instantiation
Assessment
Dynamic Bayesian Networks
GIS Mapping
Design of Experiments
WebSimulator Editor
Compare
Associated graph 5.xbl *
Longitude
Time (h)
Latitude
Latitude (2)
Joint Probability: 100.00%
Log-Loss: 0
Cases: 997
Total Value: -89.271
Mean Value: -17.854
Time (h)
Mean: 18.797 Dev: 12.915
Value: 18.133
7.99% <=4
12.80% <=8
15.18% <=12
14.65% <=16
12.07% <=20
9.36% <=24
6.68% <=28
6.25% <=32
15.01% >32
Latitude
Mean: 38.161 Dev: 4.613
Value: 38.133
1.89% <=27.31
0.88% <=28.98
4.87% <=31.14
3.08% <=32.46
1.19% <=32.735
2.47% <=33.31
1.09% <=33.495
8.41% <=34.255
7.74% <=35.95
32.15% <=40.445
0.35% <=40.495
0.95% <=40.59
6.91% <=40.895
3.88% <=41.395
2.51% <=41.71
3.69% <=42.065
6.38% <=43.07
2.44% <=43.94
2.99% <=44.99
1.25% <=45.555
0.91% <=46.095
0.35% <=46.285
1.73% <=47.29
0.38% <=47.42
1.49% >47.42
Latitude (2)
Mean: 35.990 Dev: 0.000
Value: 38.136
2.64% <=28.545
4.84% <=31.14
3.05% <=32.51
1.62% <=32.81
2.34% <=33.41
0.74% <=33.495
8.71% <=34.255
7.78% <=35.925
4.23% <=36.59
2.29% <=36.845
2.43% <=37.275
0.56% <=37.425
7.97% <=38.695
16.01% <=40.59
6.27% <=40.875
1.68% <=41.045
0.26% <=41.065
4.95% <=41.71
3.49% <=42.065
6.86% <=43.155
4.69% <=44.955
6.59% >44.955
Longitude
Mean: -91.836 Dev: 15.481
Value: -91.762
2.05% <=-122.475
4.19% <=-121.01
0.79% <=-119.68
7.38% <=-116.87
0.85% <=-115.665
1.07% <=-112.175
2.55% <=-110.135
2.13% <=-105.675
2.40% <=-101.98
9.38% <=-95.845
1.32% <=-95.51
0.69% <=-95.34
6.89% <=-91.705
6.89% <=-88.3
2.70% <=-87.665
1.21% <=-87.325
6.17% <=-84.755
4.61% <=-83.675
8.38% <=-80.445
2.08% <=-80.1
14.63% <=-74.22
4.63% <=-73.865
2.13% <=-73.22
3.91% <=-69.87
0.94% >-69.87
Associa...
Associa...


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Associated graph 5.xbl *
Longitude
Longitude (2)
Time (h)
Latitude
Latitude (2)
Joint Probability: 100.00%
Log-Loss: 0
Cases: 997
Total Value: -89.271
GIS Mapping
Map Settings
Map Type Roads
Latitude Latitude
Longitude Longitude
Shape
Fixed CIRCLE
Discrete Latitude (2)
Size
Fixed 100
Discrete Latitude (2)
Continuous Latitude (2)
Color
Fixed
Discrete Latitude (2)
Continuous Time (h)
Min Mid Max
Opacity
Fixed 1
Discrete Latitude (2)
Continuous Latitude (2)
OK
Cancel
Latitude
Mean: 38.161 Dev: 4.613
Value: 38.133
Latitude (2)
Mean: 35.990 Dev: 0.000
Value: 38.136


BayesiaLab - C:\Users\StefanConradv\OneDrive - Bayesia USA\Studies\GIS\Demo\Associated graph 5.xbl
Network Data Edit View Learnin
Associated graph 5.xbl *
Map
Map
Canada
ALBERTA
MANITOBA
BRITISH COLUMBIA
SASKATCHEWAN
NEWFOUNDLAND AND LABRADOR
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
NOVA SCOTIA
NB
PE
MONTANA
WYOMING
NEVADA
UTAH
ARIZONA
NEW MEXICO
Las Vegas
Los Angeles
San Diego
TEXAS
Gulf of California
Gulf of Mexico
Mexico
Mexico City
Cuba
Dominican Republic
Puerto Rico
Guatemala
Honduras
Nicaragua
Costa Rica
Caribbean Sea
Caracas
Map data ©2018 Google, INEGI
500 km
Terms of Use
Close
Save As...
Print
Longitude
Latitude
Longitude (2)
Mean: -86.900 Dev: 0.000
Value: -91.911
2.20% <=-122.475
1.29% <=-122.095
2.42% <=-121.285
1.16% <=-119.675
7.33% <=-116.945
1.31% <=-115.215
0.50% <=-114.595
2.91% <=-110.135
2.40% <=-105.275
1.26% <=-103.095
6.01% <=-97.41
4.95% <=-95.765
1.68% <=-95.34
5.38% <=-92.185
11.16% <=-87.545
9.48% <=-84.155
0.80% <=-83.98
0.70% <=-80.025
1.09% <=-80.445
2.25% <=-80.06
14.14% <=-74.315
4.83% <=-73.865
2.02% <=-73.22
3.70% <=-69.87
0.95% >-69.87
<=28.545
<=31.14
<=32.51
<=32.81
<=33.41
<=33.495
<=34.255
<=35.925
<=36.59
<=36.845
<=37.275
<=37.425
<=38.695
<=40.59
<=40.875
<=41.045
<=41.065
<=41.71
<=42.065
<=43.155
<=44.955
>44.955

Drive Time Bands

Computing the Cost

- "Search the Map" ➔ slow, but accurate
- Great-Circle Distance Computation ➔ fast, but inaccurate
- Learn & Infer ➔ fast and good approximation

BAYESIALAB

Spatial Learning and Optimization

Hub Location

Spatial Learning and Optimization

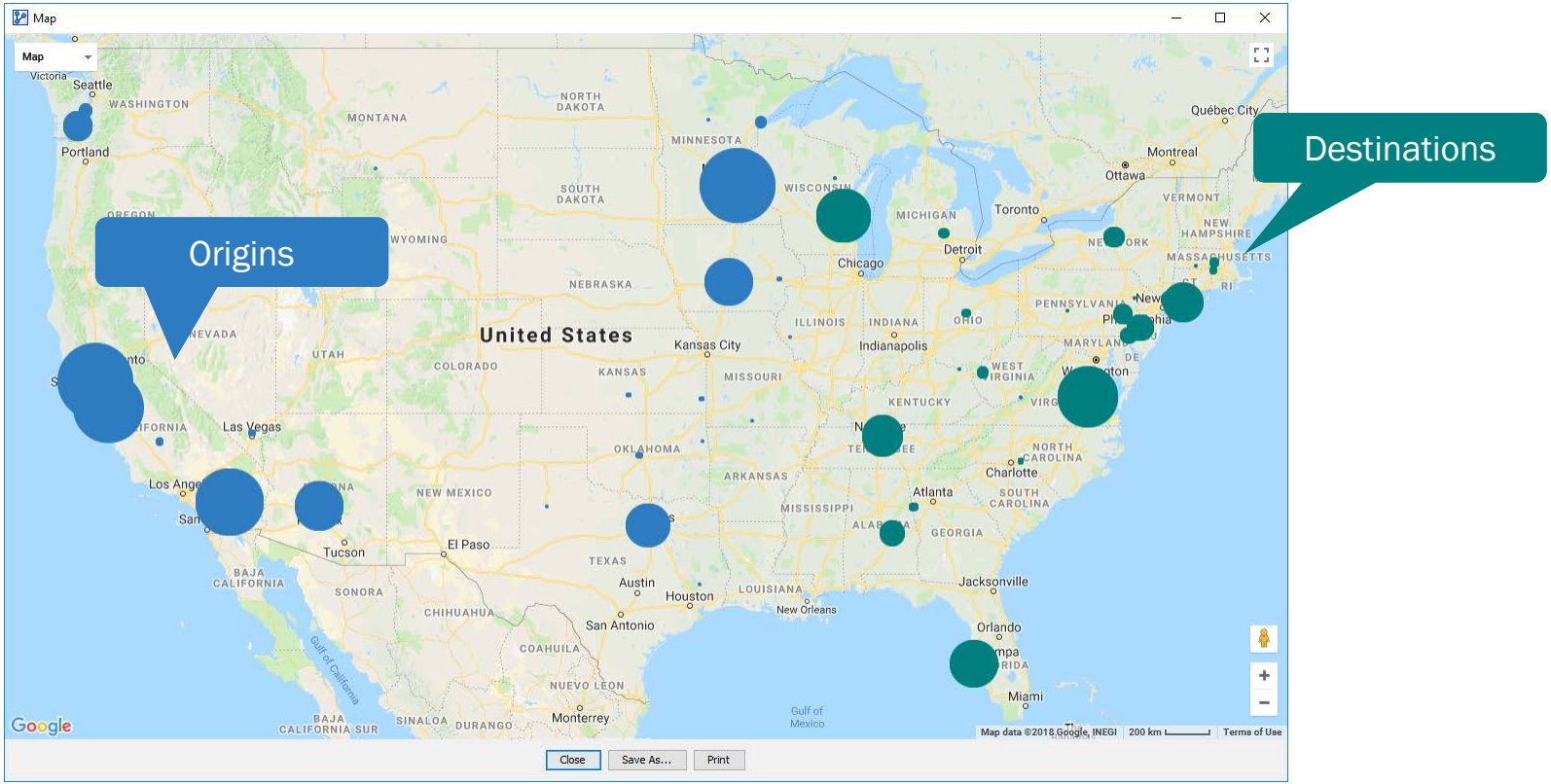
Optimization Problems Under Consideration

1. One origin, one destination ➔ Shortest Path Problem
2. One origin, many destinations ➔ Drive Time Bands
3. Many origins, one destination ➔ Store Location Problem
4. Many origins, one hub, many destinations ➔ Hub Location Problem
5. Many origins, multiple hubs, many destinations ➔ Multi-Hub Location Problem

General Objective

- Minimize “cost function,” e.g., travel time, distance, fuel consumption, number of turns, etc.
- Further assumption: all “participants” have same objective.

Hub Location Problem

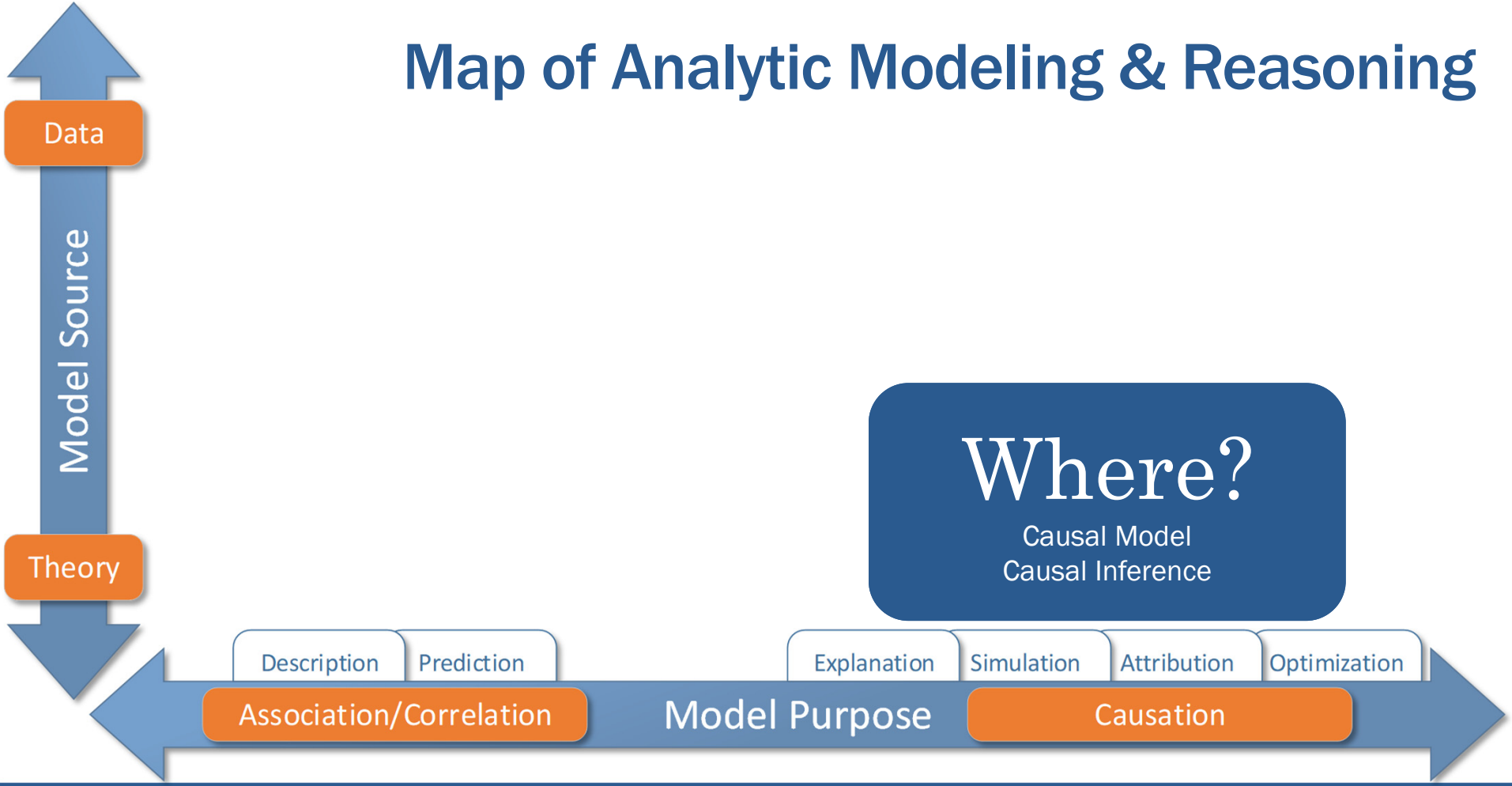


Hub Location Problem

Workflow

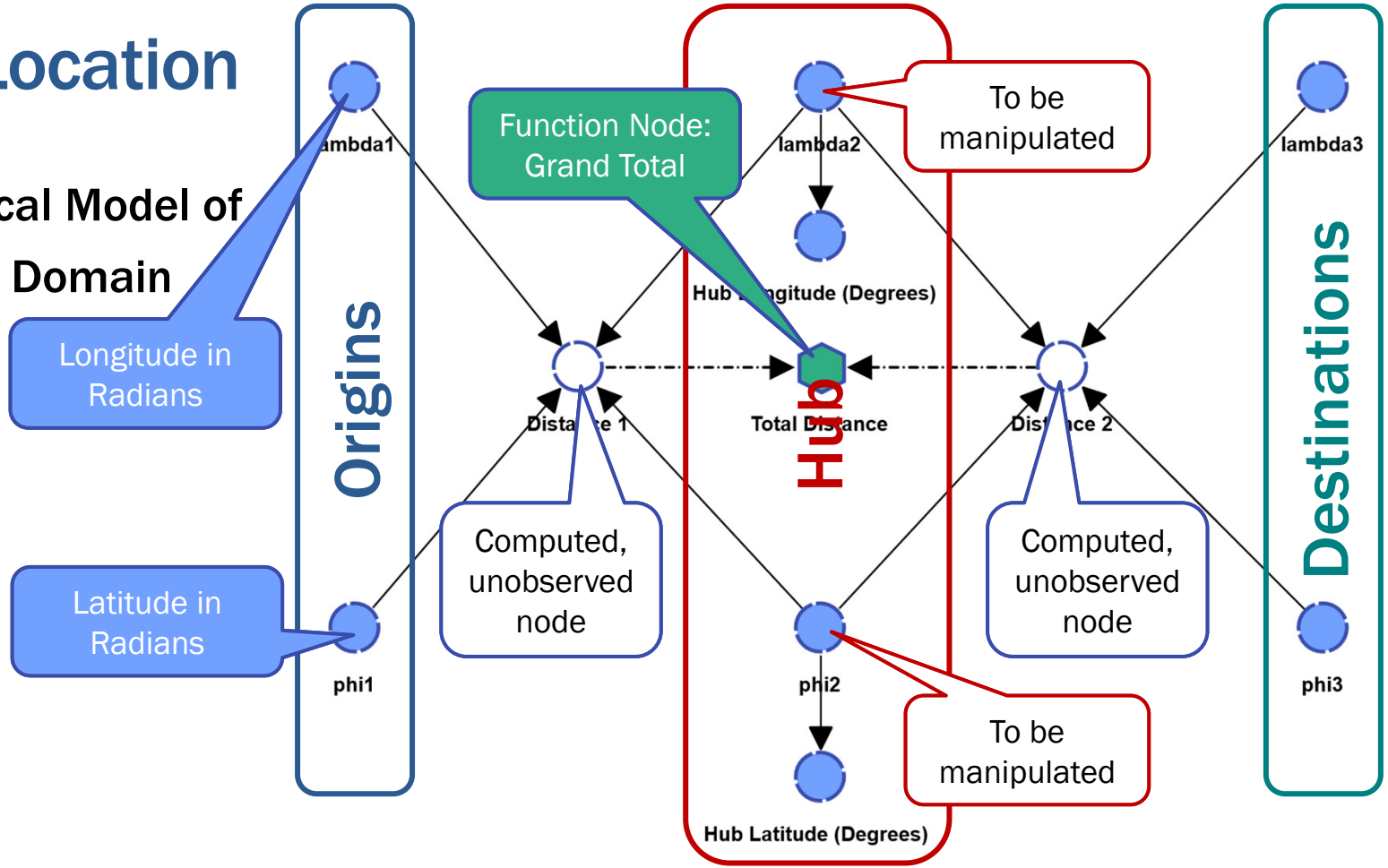
- Encode theoretical model of problem domain.
- Define Nodes
    - Observed
    - Unobserved
    - Functions
- Load data for origins and destinations.
- Perform Function Optimization.

Map of Analytic Modeling & Reasoning



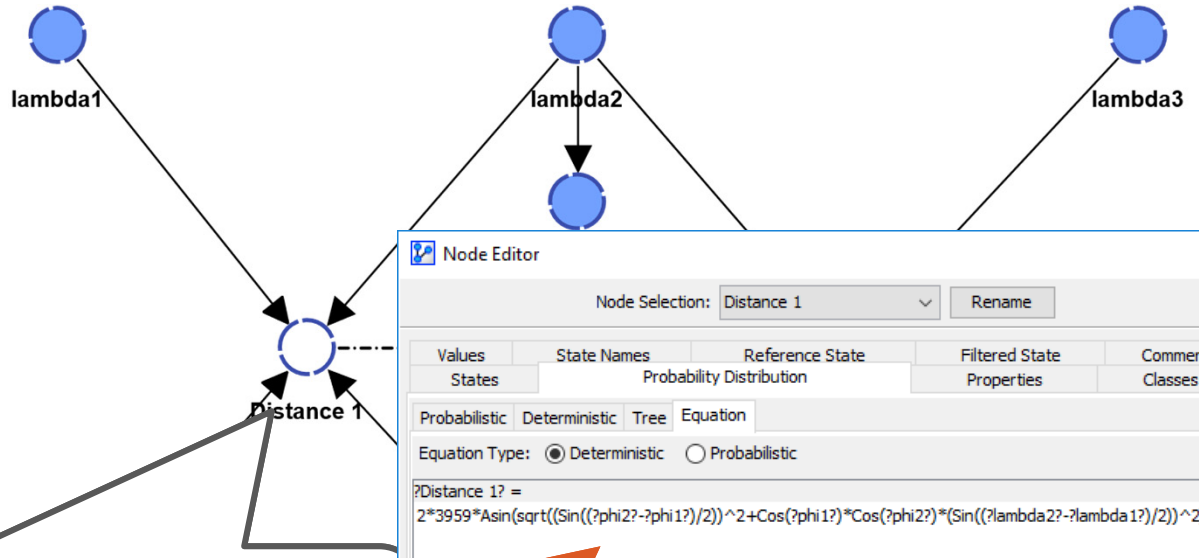
Hub Location

Theoretical Model of Problem Domain



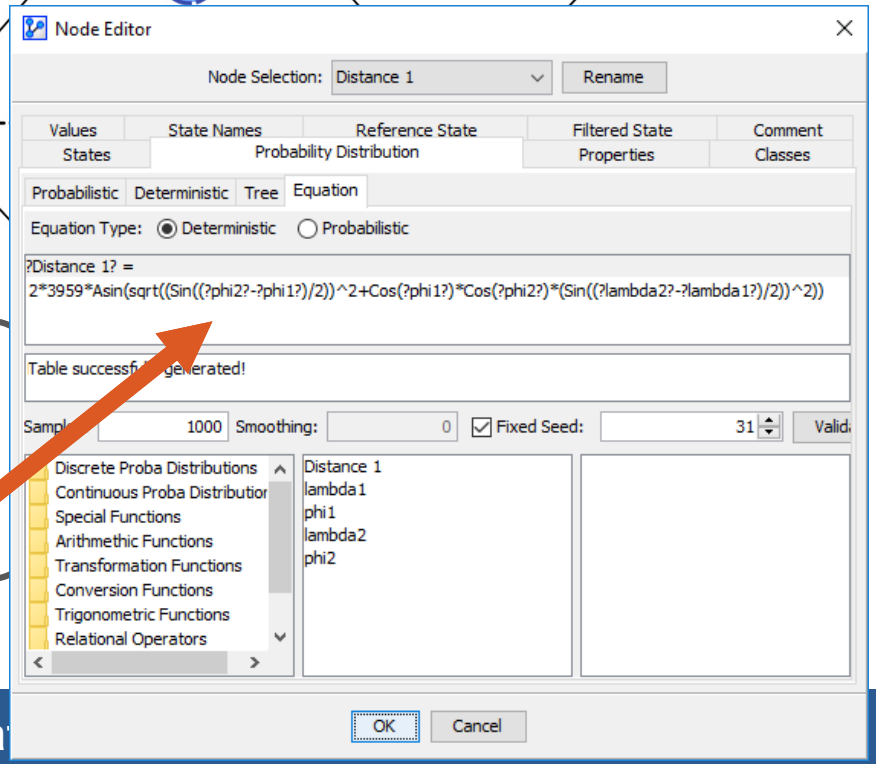
Hub Location

Theoretical Model of Problem Domain



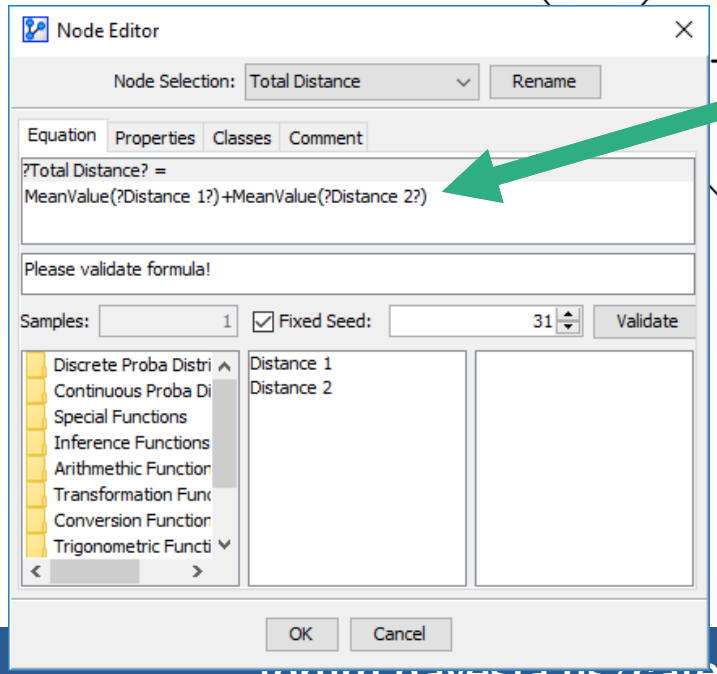
$$d = 2r \arcsin\left(\sqrt{\text{hav}(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\,\text{hav}(\lambda_2 - \lambda_1)}\right)$$

$$= 2r \arcsin\left(\sqrt{\sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2)\sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$



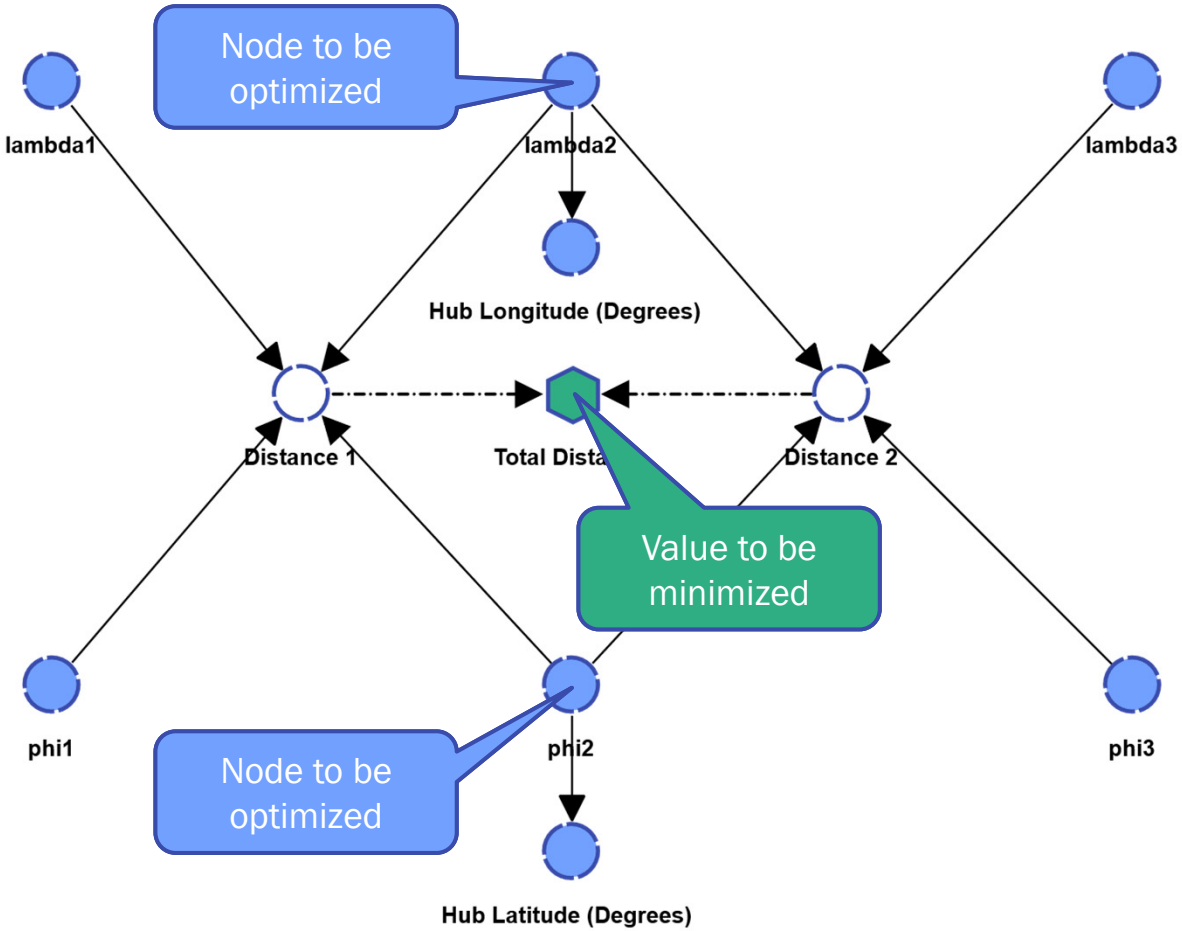
Hub Location

Theoretical Model of Problem Domain



Hub Location

Theoretical Model of Problem Domain

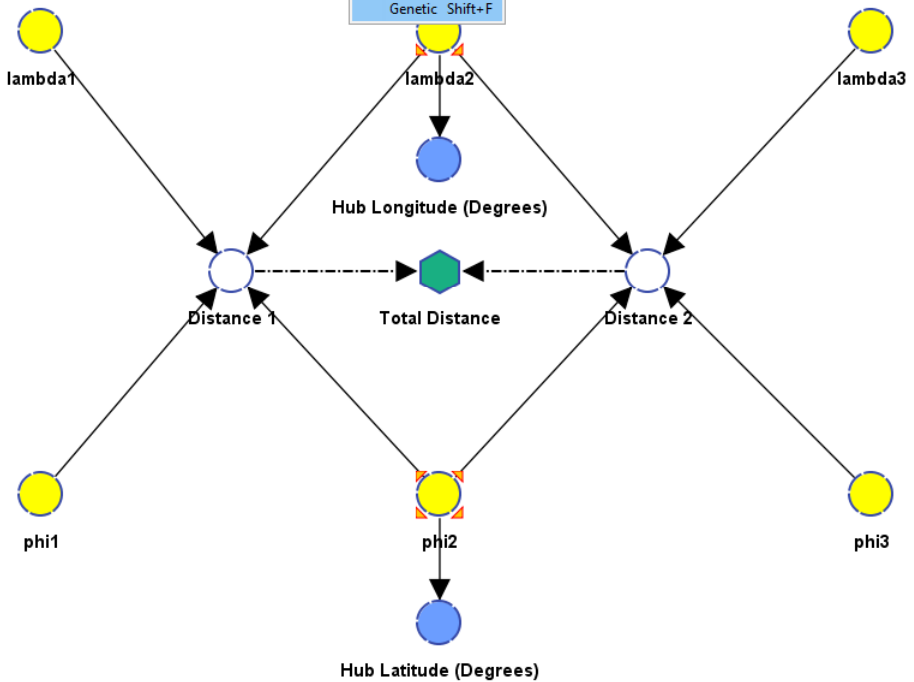


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\3 Hub Location\Hub Radians Reference 2.xbl

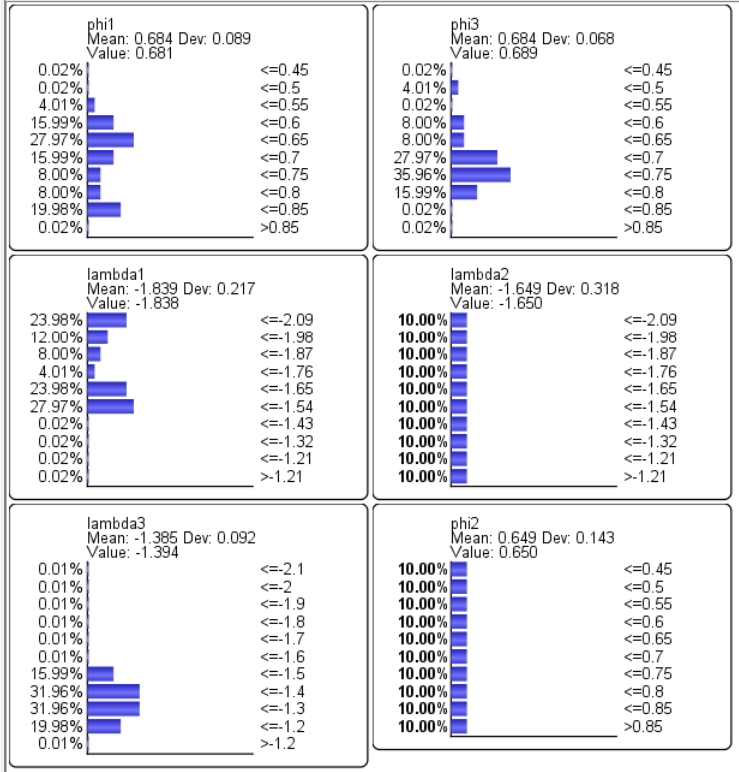
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Visual
Report
Network Performance
Target Optimization
Function Optimization
Greedy
Tree
Genetic Shift+F

Hub Radians Reference 2.xbl



Joint Probability: 100.00%
Log-Loss: 0
Cases: 625
Total Value: 2,546.527
Mean Value: 254.653



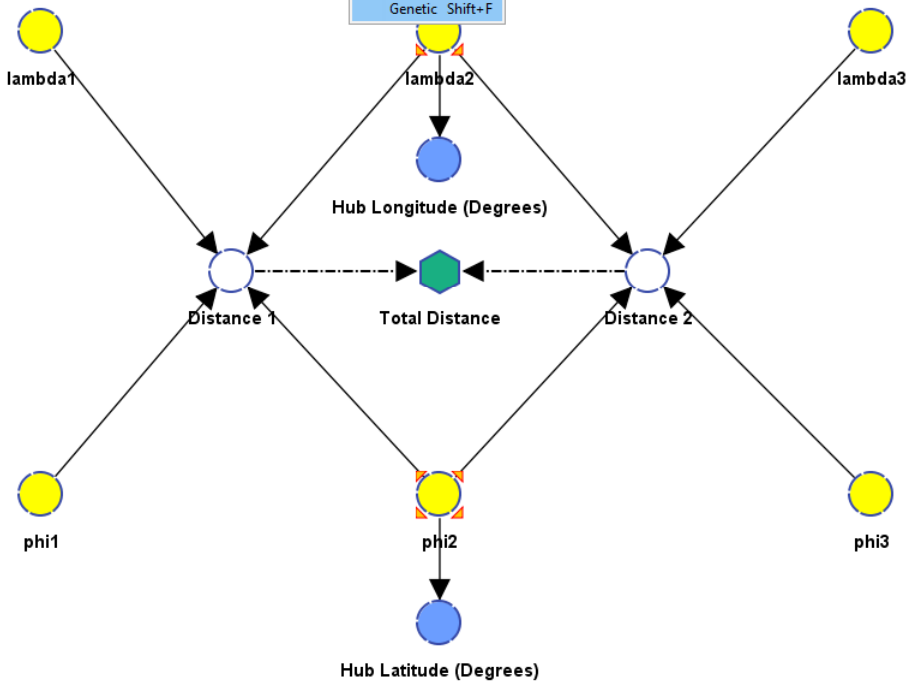
Hub Ra...

BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\3 Hub Location\Hub Radians Reference 2.xbl

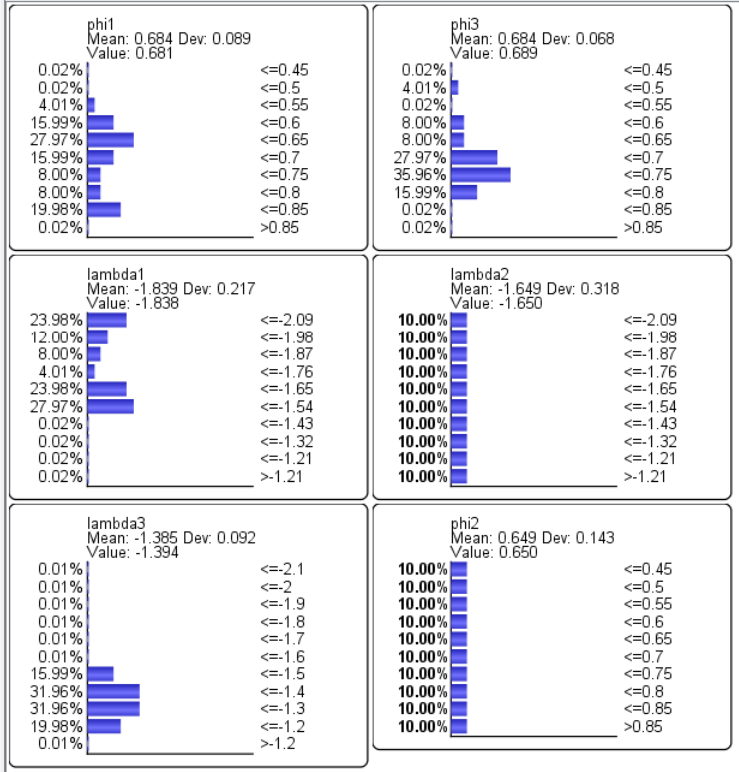
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help

Visual
Report
Network Performance
Target Optimization
Function Optimization
Greedy
Tree
Genetic Shift+F

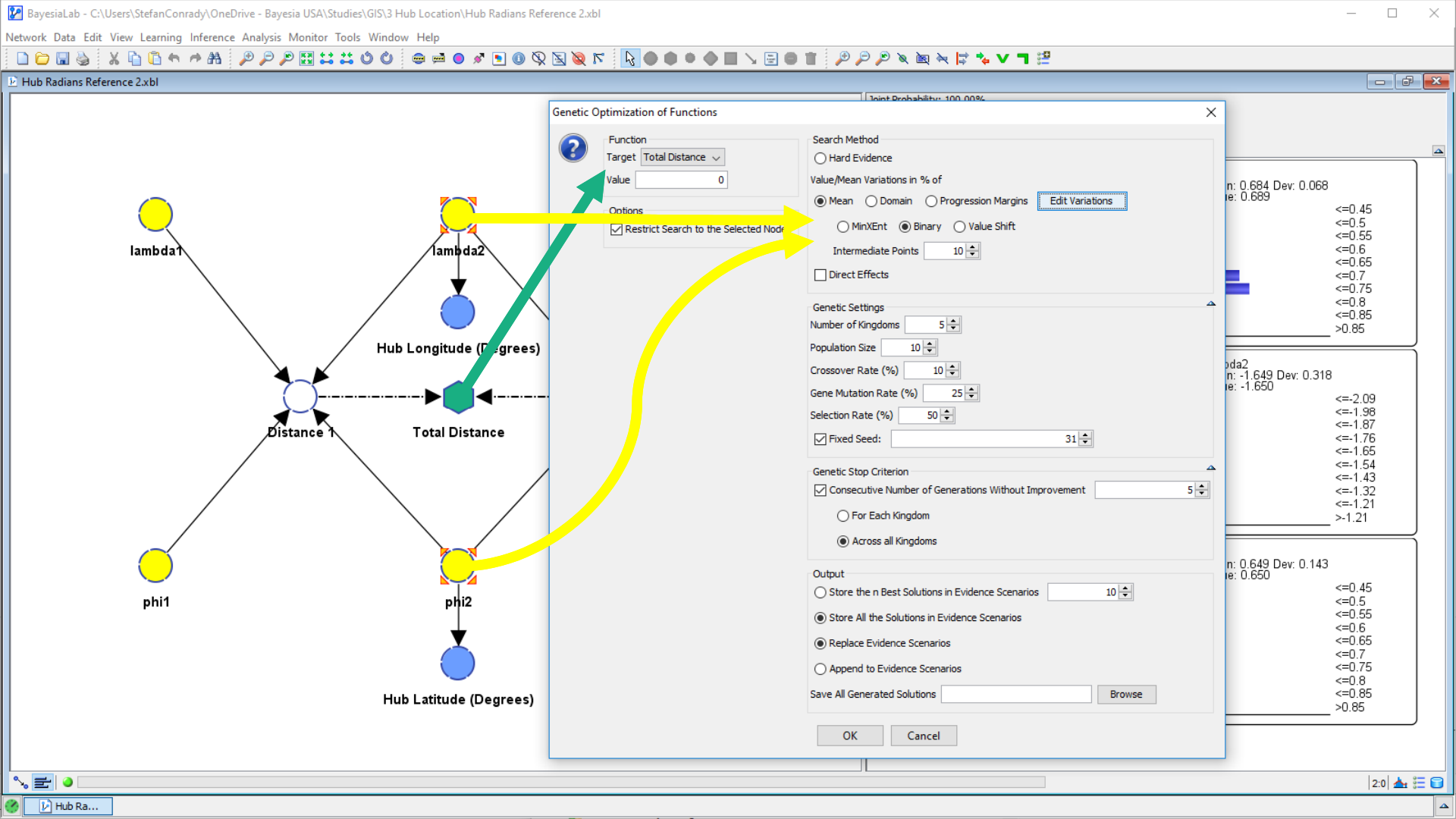
Hub Radians Reference 2.xbl

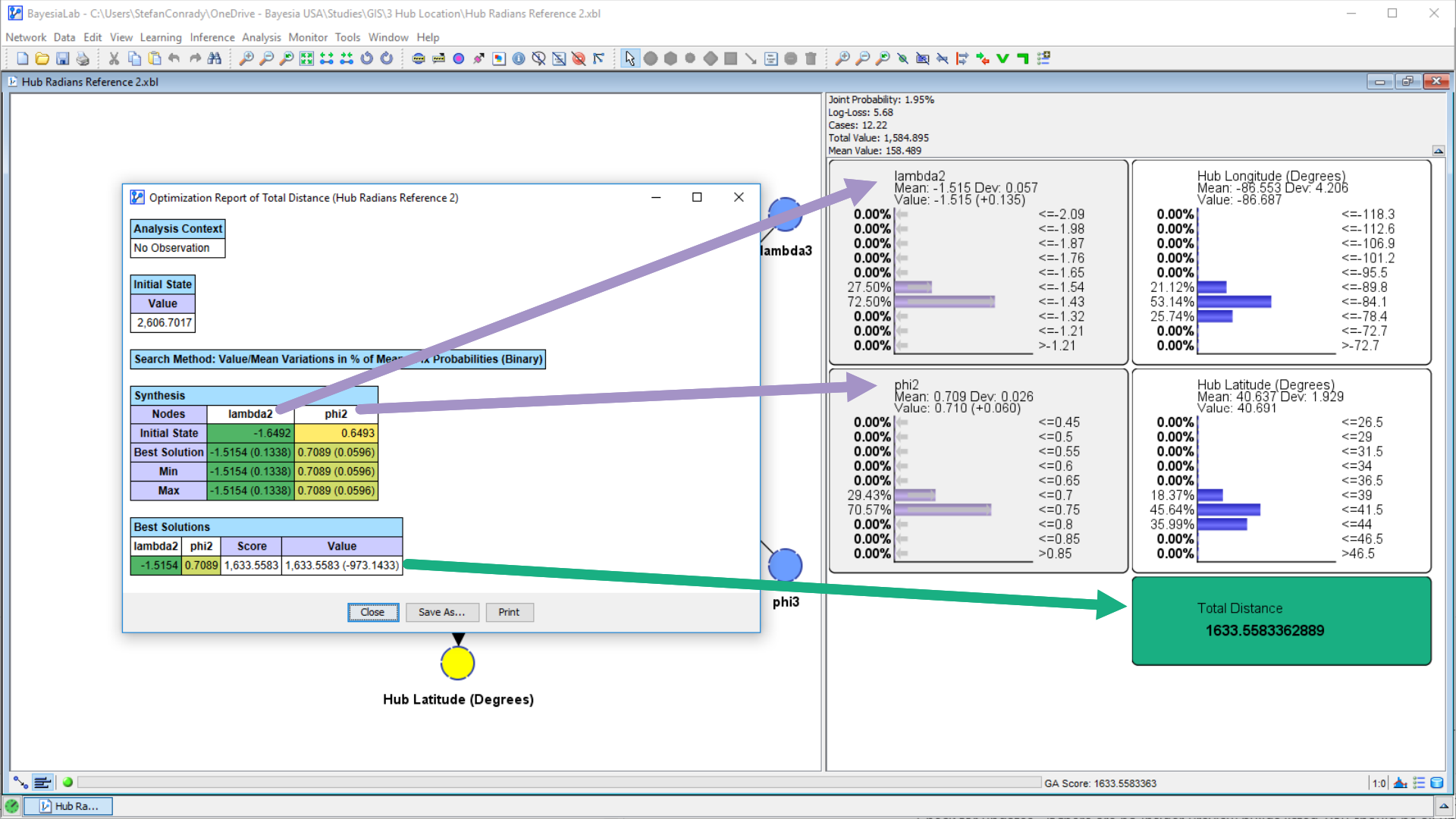


Joint Probability: 100.00%
Log-Loss: 0
Cases: 625
Total Value: 2,546.527
Mean Value: 254.653

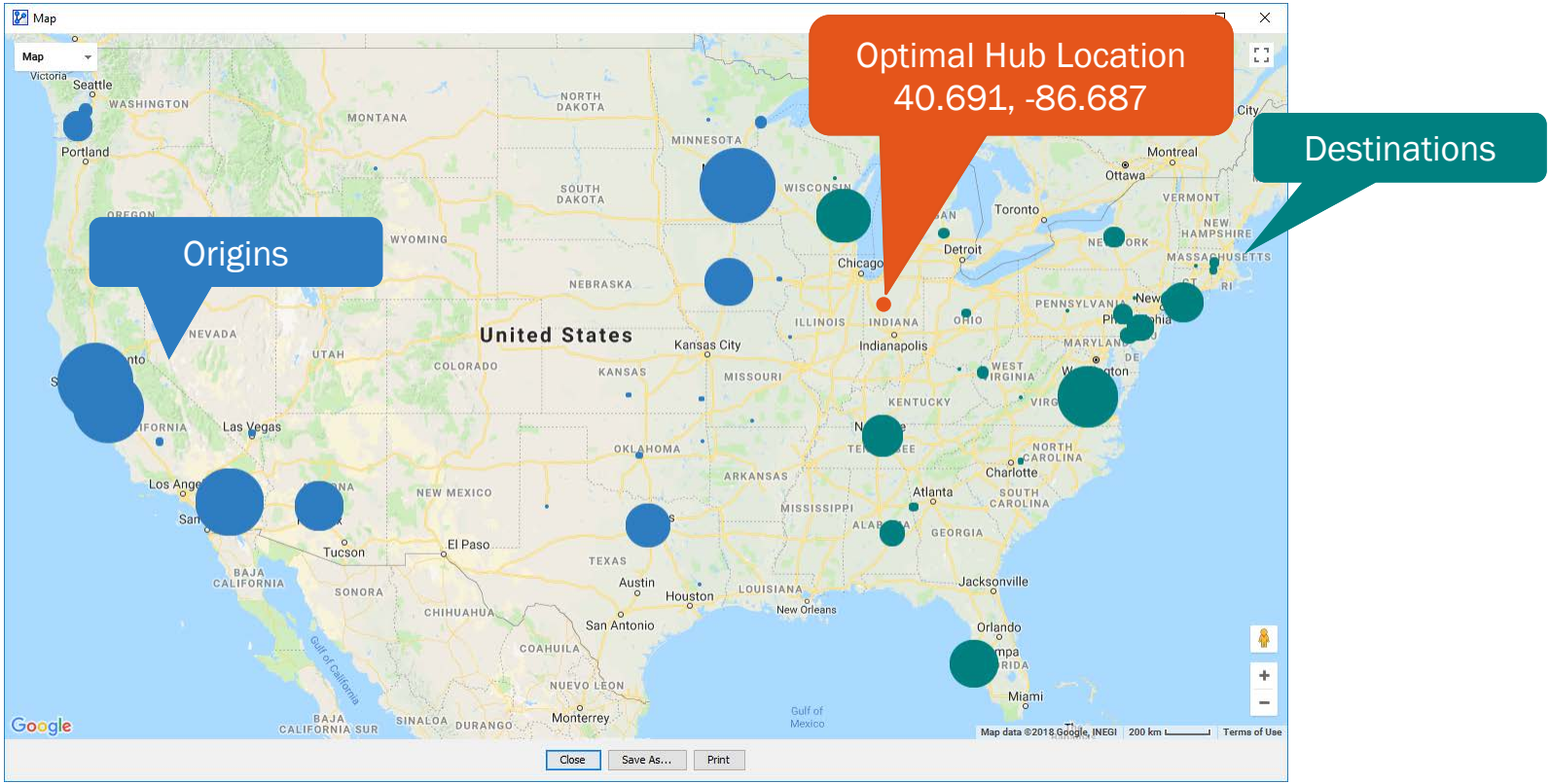


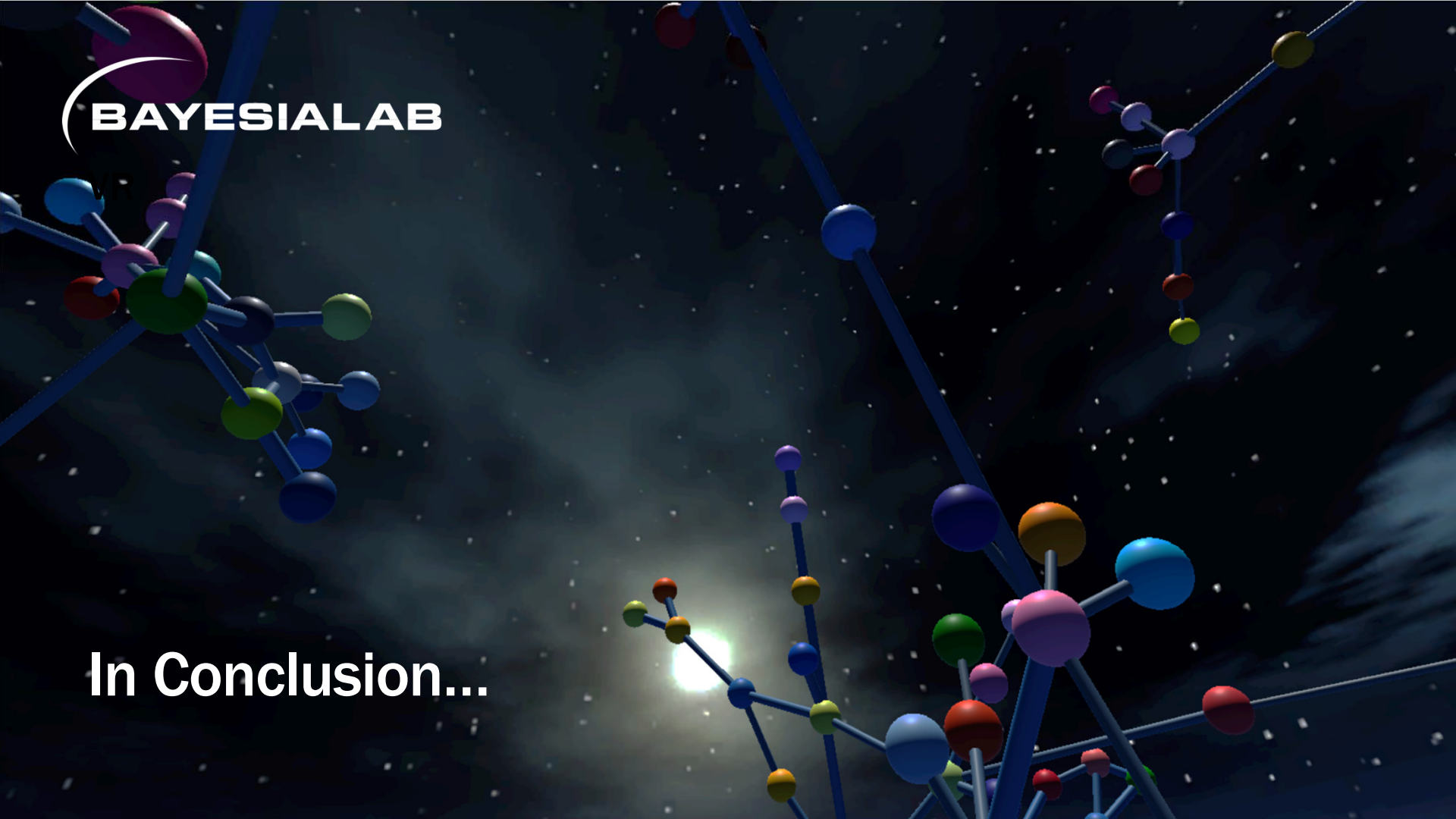
Hub Ra...


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\3 Hub Location\Hub Radians Reference 2.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Hub Radians Reference 2.xbl
lambda1
lambda2
Hub Longitude (Degrees)
Distance 1
Total Distance
phi1
phi2
Hub Latitude (Degrees)
Genetic Optimization of Functions
Function
Target Total Distance
Value 0
Options
Restrict Search to the Selected Node
Search Method
Hard Evidence
Value/Mean Variations in % of
Mean Domain Progression Margins Edit Variations
MinXEnt Binary Value Shift
Intermediate Points 10
Direct Effects
Genetic Settings
Number of Kingdoms 5
Population Size 10
Crossover Rate (%) 10
Gene Mutation Rate (%) 25
Selection Rate (%) 50
Fixed Seed: 31
Genetic Stop Criterion
Consecutive Number of Generations Without Improvement 5
For Each Kingdom
Across all Kingdoms
Output
Store the n Best Solutions in Evidence Scenarios 10
Store All the Solutions in Evidence Scenarios
Replace Evidence Scenarios
Append to Evidence Scenarios
Save All Generated Solutions
Browse
OK
Cancel
n: 0.684 Dev: 0.068
e: 0.689
<=0.45
<=0.5
<=0.55
<=0.6
<=0.65
<=0.7
<=0.75
<=0.8
<=0.85
>0.85
n: -1.649 Dev: 0.318
e: -1.650
<=-2.09
<=-1.98
<=-1.87
<=-1.76
<=-1.65
<=-1.54
<=-1.43
<=-1.32
<=-1.21
>-1.21
n: 0.649 Dev: 0.143
e: 0.650
<=0.45
<=0.5
<=0.55
<=0.6
<=0.65
<=0.7
<=0.75
<=0.8
<=0.85
>0.85


BayesiaLab - C:\Users\StefanConrady\OneDrive - Bayesia USA\Studies\GIS\3 Hub Location\Hub Radians Reference 2.xbl
Network Data Edit View Learning Inference Analysis Monitor Tools Window Help
Hub Radians Reference 2.xbl
Joint Probability: 1.95%
Log-Loss: 5.68
Cases: 12.22
Total Value: 1,584.895
Mean Value: 158.489
Optimization Report of Total Distance (Hub Radians Reference 2)
Analysis Context
No Observation
Initial State
Value
2,606.7017
Search Method: Value/Mean Variations in % of Mea x Probabilities (Binary)
Synthesis
Nodes lambda2 phi2
Initial State -1.6492 0.6493
Best Solution -1.5154 (0.1338) 0.7089 (0.0596)
Min -1.5154 (0.1338) 0.7089 (0.0596)
Max -1.5154 (0.1338) 0.7089 (0.0596)
Best Solutions
lambda2 phi2 Score Value
-1.5154 0.7089 1,633.5583 1,633.5583 (-973.1433)
Close
Save As...
Print
lambda3
phi3
Hub Latitude (Degrees)
lambda2
Mean: -1.515 Dev: 0.057
Value: -1.515 (+0.135)
0.00% <=-2.09
0.00% <=-1.98
0.00% <=-1.87
0.00% <=-1.76
0.00% <=-1.65
27.50% <=-1.54
72.50% <=-1.43
0.00% <=-1.32
0.00% <=-1.21
0.00% >-1.21
Hub Longitude (Degrees)
Mean: -86.553 Dev: 4.206
Value: -86.687
0.00% <=-118.3
0.00% <=-112.6
0.00% <=-106.9
0.00% <=-101.2
0.00% <=-95.5
21.12% <=-89.8
53.14% <=-84.1
25.74% <=-78.4
0.00% <=-72.7
0.00% >-72.7
phi2
Mean: 0.709 Dev: 0.026
Value: 0.710 (+0.060)
0.00% <=0.45
0.00% <=0.5
0.00% <=0.55
0.00% <=0.6
0.00% <=0.65
29.43% <=0.7
70.57% <=0.75
0.00% <=0.8
0.00% <=0.85
0.00% >0.85
Hub Latitude (Degrees)
Mean: 40.637 Dev: 1.929
Value: 40.691
0.00% <=26.5
0.00% <=29
0.00% <=31.5
0.00% <=34
0.00% <=36.5
18.37% <=39
45.64% <=41.5
35.99% <=44
0.00% <=46.5
0.00% >46.5
Total Distance
1633.5583362889
GA Score: 1633.5583363
Hub Ra...

Hub Location Problem




BAYESIALAB
In Conclusion...

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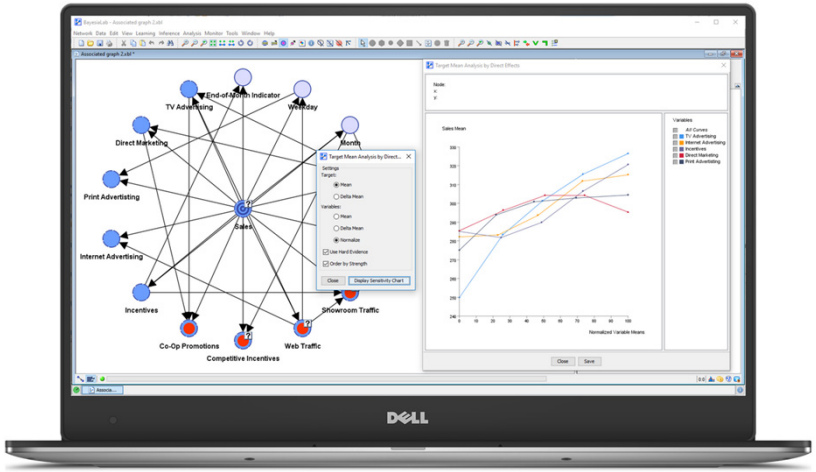
  www.bayesialab.com/trial-download
- Apply for Unrestricted Evaluation Version:
  www.bayesialab.com/evaluation



Webinar Series

Reasoning Under Uncertainty

- March 20 Part 1 — Differential Diagnosis of Diseases
- March 26 Part 2 — Pandemic Triage with Bayesian Networks
- April 9 Part 3 — Epidemic Modeling with Temporal Bayesian Networks
- April 30 Part 4 — Representing Spatial and Temporal Dynamics
- t.b.d. Part 5 — “Test & Treat” vs. Presumptive Treatment Policy

Program Subject to Change — Check for Updates

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8th Annual BayesiaLab Conference

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Thank you and be safe!

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