Risk Analysis:
The Role of Bayesian Networks

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• Intelligence / Risk Analysis in Context
• Bayes Net Overview
• UNBBayes Background and Instructions
• Loading an existing network
• Simulating outcomes
• Learning Networks in UNBBayes
1. To explain, account for, or describe a phenomenon
2. To predict, forecast, or estimate.

To Support Better Decisions!
The Amount of Data Exceeds Capacity

**FIXES**
- **Policy**
  - Info Sharing / Federated / Coalition Production
  - Security
  - Archiving / Storage

- **Technology**
  - Automation / Filters / OBP / “Fusion” / Cross-Cueing / ACD

- **Procedures**
  - Collaborative Tasking & Production / Collection Mgt
  - Training / “Best Practices”

- **Resources**
  - More People (Government / Contractor / Academia)
  - Linguists / Translation

**Sources of and Issues with Data**
- GEOINT
- HUMINT
- SIGINT
- MASINT
- OSINT

**Requirements & Data Collection**
- Expectations Of Analysis
- Intelligence PED

**Actual Intelligence**
- Volume
  - Velocity
  - Variety
  - Veracity

**Intelligence FAILURE**

**TODAY**

**TIME**

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Bayes Net Overview (1 of 5)

h₁: has capability
h₂: no capability
e₁: supports h₁
e₂: supports h₂

\[
egin{align*}
\text{p}(E=e₁ | H=h₁) &= q = .6 \\
\text{p}(E=e₂ | H=h₁) &= (1-q) = .4 \\
\text{p}(E=e₁ | H=h₂) &= r = .1 \\
\text{p}(E=e₂ | H=h₂) &= (1-r) = .9
\end{align*}
\]

\[
\begin{align*}
\text{p}(E=e₁) &= (p*q)+[(1-p)*r) = .35 \\
\text{p}(E=e₂) &= [p*(1-q)]+[(1-p)*(1-r)] = .65
\end{align*}
\]

Prior Marginal Probability Distributions

p(e₁ ,h₁) = .175
p(e₁ ,h₂) = .175
p(e₂, h₁) = .325
p(e₂, h₂) = .325

State Probabilities

From: Maxwell (1998)
Bayesian Networks are designed to implement Bayes Rule.
A probability technique that combines subjective probability and data.

$$
\begin{align*}
\text{p}(E=e_1|H=h_1) &= q = .6 \\
\text{p}(E=e_2|H=h_1) &= (1-q) = .4 \quad \text{ Conditional} \\
\text{p}(E=e_1|H=h_2) &= r = .1 \quad \text{ Probability} \\
\text{p}(E=e_2|H=h_2) &= (1-r) = .9 \quad \text{ Distributions} 
\end{align*}
$$

**Posterior Probabilities**

$$
\begin{align*}
\text{p}(H=h_1) &= .86 \\
\text{p}(H=h_2) &= .14 \\
\text{p}(E=e_1) &= 1.0 \\
\text{p}(E=e_2) &= 0.0
\end{align*}
$$
Models can be relatively simple

Or very complex
Bayes Nets (4 of 5) -- Commercial Examples

Startup Investment Assessment

Commercial Sales Forecasting

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Bayes Nets (5 of 5) -- National Security Risk Related

Technology Forecasting

Forecasting Country Stability

From Netica

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Model Results For Forecasting Instability

Probability of Violent Instability

- Alert Desk Officer

Time

Probability

1 2 3 4 5 6 7 8 9 10 11
Bayes Nets are not a Silver Bullet!!!
- They are an element of a toolkit

Bayes Nets do provide:
- an internally consistent mathematical engine for estimating likelihoods
- the ability to integrate (Fuse) subjective (human) beliefs and objective (sensor based) data
- A chain of logic that is explainable to decision makers

When not to use Bayes Nets
- When The Question is not yet clear
- When data is highly unstructured and not able to be structured (That subset is shrinking)
- When data is extremely ambiguous
Some Sources of Bayes Net Software

- Commercial
  - NETICA – NORSYS (www.norsys.com)
  - Bayesia – Bayesia Labs (www.bayesia.com)
  - Hugin Expert -- www.hugin.com
- Academic
  - GeNie – University of Pittsburgh
    - Free for academic use
    - commercial offering called Bayes Fusion (www.bayesfusion.com)
- Open Source
  - UNBBayes – Instituto Tecnológico da Aeronáutica, Brazil
    (https://sourceforge.net/projects/unbbayes/)
  - “R” – The R Project for Statistical Computing (www.r-project.org/)
• UNBBayes is open source software currently available under a GPL license

• GoTo -- [https://sourceforge.net/projects/unbbayes/](https://sourceforge.net/projects/unbbayes/)
  – Download UNBBayes Core
  – Download Plug in Framework
    • Learning
    • Simulation

• Ensure the Plug in code is located in the plug ins folder
Launch UNBBayes using either the Jar (Apple) or .bat (Windows) file

Use these icons to add nodes and arcs
Two Node Network
Simulation

Sample size: [ ]

OK
• A text File

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Sample Size Matters in Learning and Consequently in Fusion

Ground truth was 50-50 over the hypothesis

Sample of 10

Sample of 10,000

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• Smith, C. ... & Maxwell, D. “Quantitative Approaches to Representing the Value of Information within the Intelligence Cycle”, International Journal of Strategic Decision Sciences, Vol. 6, no.4, December 2015, pp. 1-22