ASSESMENT OF EFFECTS-BASED OPERATIONS USING TEMPORAL LOGIC

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The Future of C2
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Outline

- Effects Based Approach
  - Research Pedigree
  - Influence Nets
  - Timed Influence Nets
- Assessment
  - Temporal Analysis
- Application
- Conclusion

Effects Based Approach

- Set of Actions/Tasks with Impact on Desired and/or Undesired Consequences
- The Political and Strategic Objectives Are to Achieve Certain Effects Subject to a Number of Constraints (e.g., Causal, Temporal, etc.)
- The Question:

  What Combination of Time-phased Actions/Tasks (COA) Will Produce The Desired Effects?

  - Determination of The Set of Tasks or Actionable Events
  - Determination of The Causal and Temporal Constraints
  - Formulation of an Analytical Framework for Modeling and Analysis
  - …

Research Pedigree

1998

Executable Models of Influence Nets using Design/CPN

Wagenhals, Shin, & Levis

Course of Action Development and Evaluation

Wagenhals, Shin, & Levis
1998 CCRTS

2000

Course of Action Development and Evaluation

Wagenhals & Levis
2000 CCRTS

2001

Equivalent Colured Petri Net Models of a Class of Timed Influence Nets with Logic

Lindstorm & Haider

Course of Action Analysis for Coalition Operations

Wagenhals, Reid, Smillie, & Levis
6th ICCRTS

An Architecture for Decision Support in a Wargame

Bienvenu, Wagenhals, Shin, & Levis
6th ICCRTS

2002

Modeling Support of Effect-Based Operations in War Games

Wagenhals & Levis,
2002 CCRTS

2003

New Effects-Based Operations Models in War Games

Wagenhals & Wentz
8th ICCRTS

Effects-Based Operations; A Historical Perspective for a Way Ahead

Wagenhals, Levis, & McCrabb
8th ICCRTS

Information Operations in Effects Based Operations: Some Observations.

Wentz & Wagenhals
8th ICCRTS

Research Pedigree

An Approximation Technique for Belief Revision in Timed Influence Nets

Haider & Levis
2004 CCRTS

Effects Based Operations for Transnational Terrorist Organizations: Assessing Alternative Courses of Action to Mitigate Terrorist Threats

Wentz & Wagenhals
2004 CCRTS

Transforming Timed Influence Nets into Time Sliced Bayesian Networks

Haider & Zaidi
2004 CCRTS

A Heuristic Approach for Best Set of Actions Determination in Influence Nets

Haider, Zaidi, & Levis
2004 IEEE IRI, Las Vegas

2004

On Temporal Analysis of Timed Influence Nets using Point Graphs

Haider, Zaidi, & Levis

Dynamic Influence Nets: An Extension of Timed Influence Nets for Modeling Dynamic Uncertain Situations

Haider & Levis
10th ICCRTS

On Finding Effective Courses of Action in a Complex Situation Using Evolutionary Algorithms

Haider & Levis
10th ICCRTS

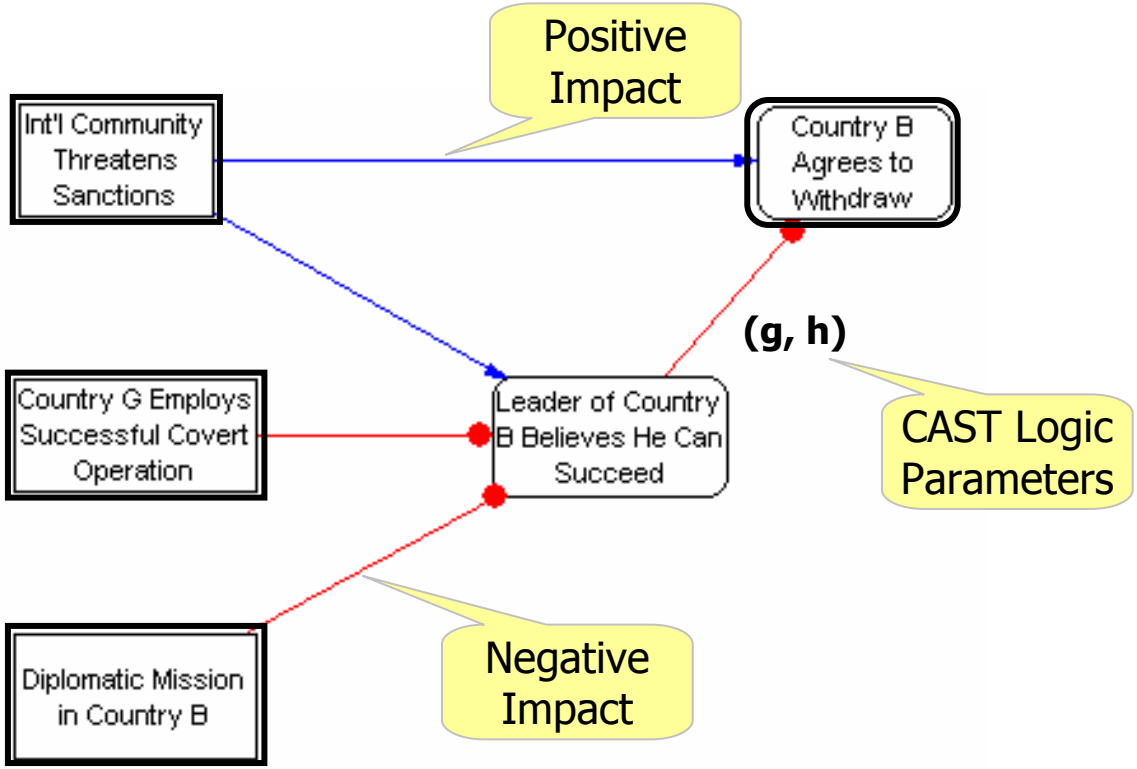
2005

Research Sponsors

- Air Force Research Laboratory (AFRL)
- Air Force Office of Scientific Research
- Office of Naval Research (ONR)
- SPAWAR Systems Center

Influence Nets

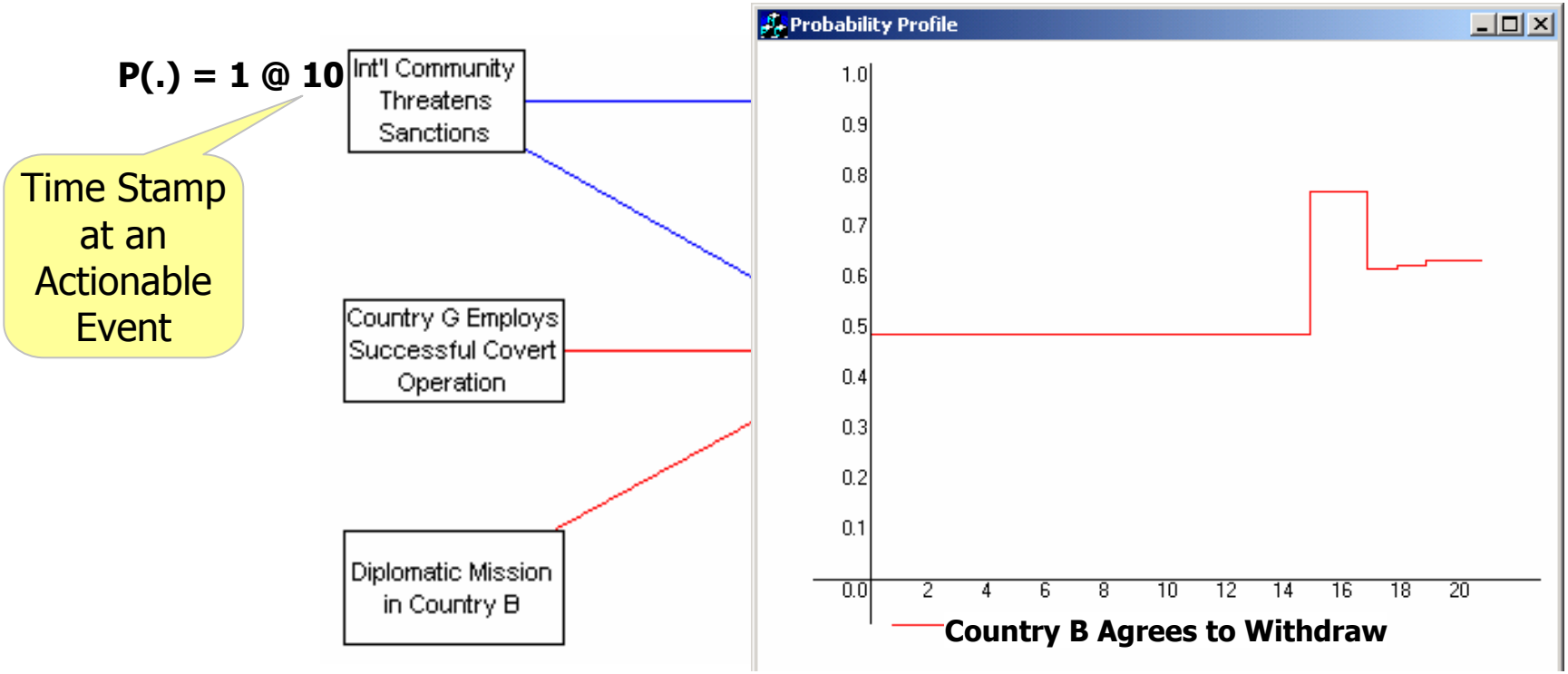
Probabilistic Belief Networks that use CAST Logic for Model Specification



- Actionable Events are Selected by Equating Corresponding Marginal Probabilities to 1
- The Posterior Probabilities of Effect Nodes are Calculated Using Bayes' Rule

Timed Influence Nets

- Variant of Dynamic Bayesian Network
- Time Delays on Arcs and Nodes



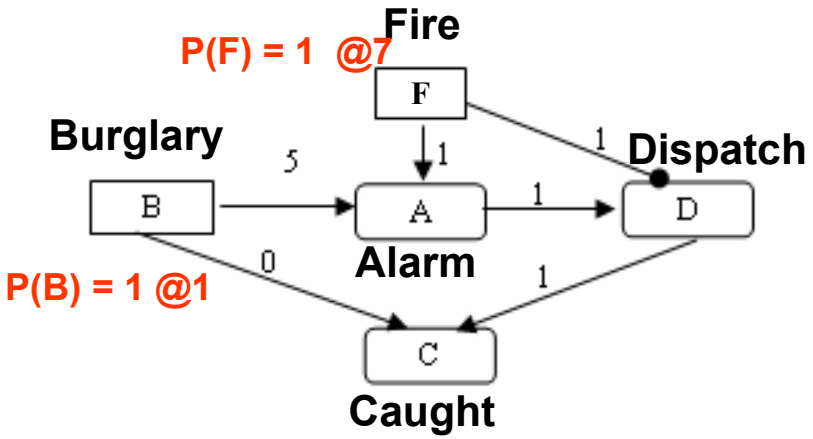
Temporal Analysis

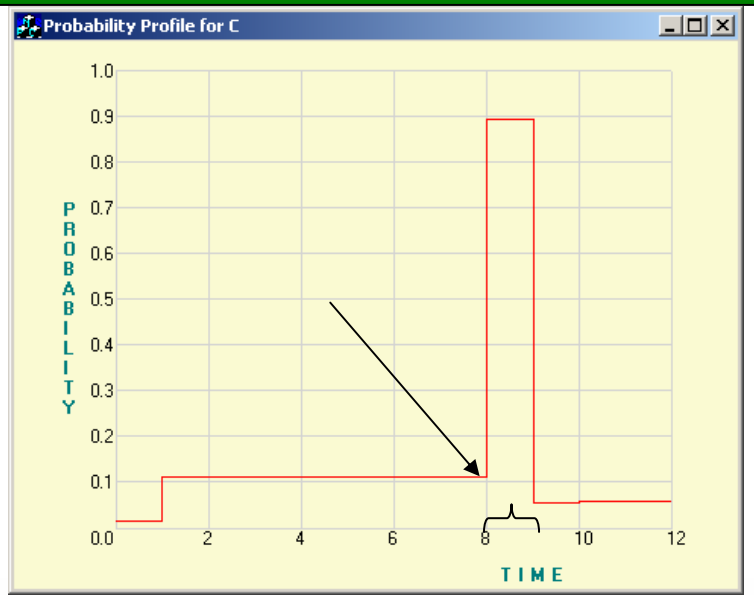
- A Path from an Actionable Event to the Desired Objective Node Represents a Timeline
- The Timeline can be Shown as a Graph with Nodes Representing Events and Arcs between Nodes Representing Precedence Relation, e.g., Before
- Analysis
  - The Timelines for Individual Actionable Events can be Merged (Folded) together to Construct the Timeline for a COA
    - History of each Influence can be Traced on this Timeline
    - Queries Regarding the History of an Influence can be Answered

  OR

  - The Time Stamps at the Objective Node(s) can be Specified and the Resulting Timing on the Actionable Events Can be Determined by Tracing Back the Timeline
    - What-If Analysis

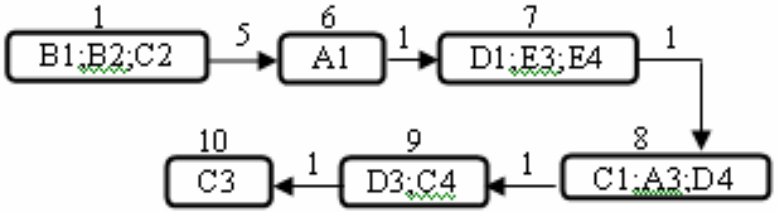
Temporal Analysis



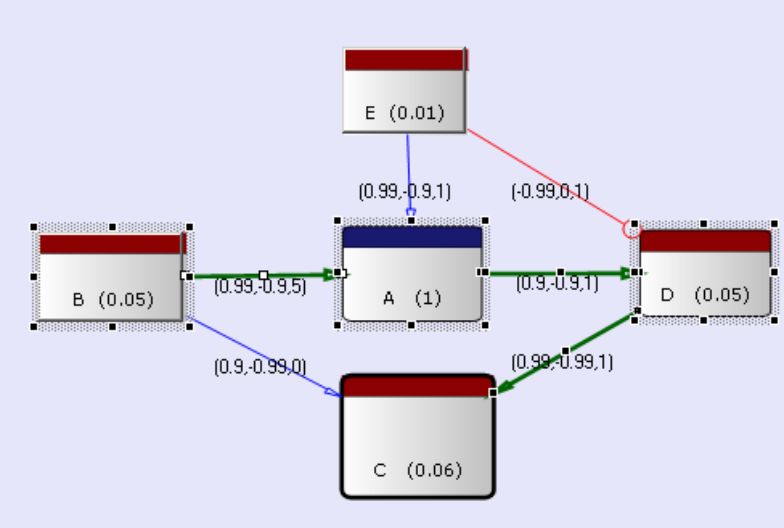


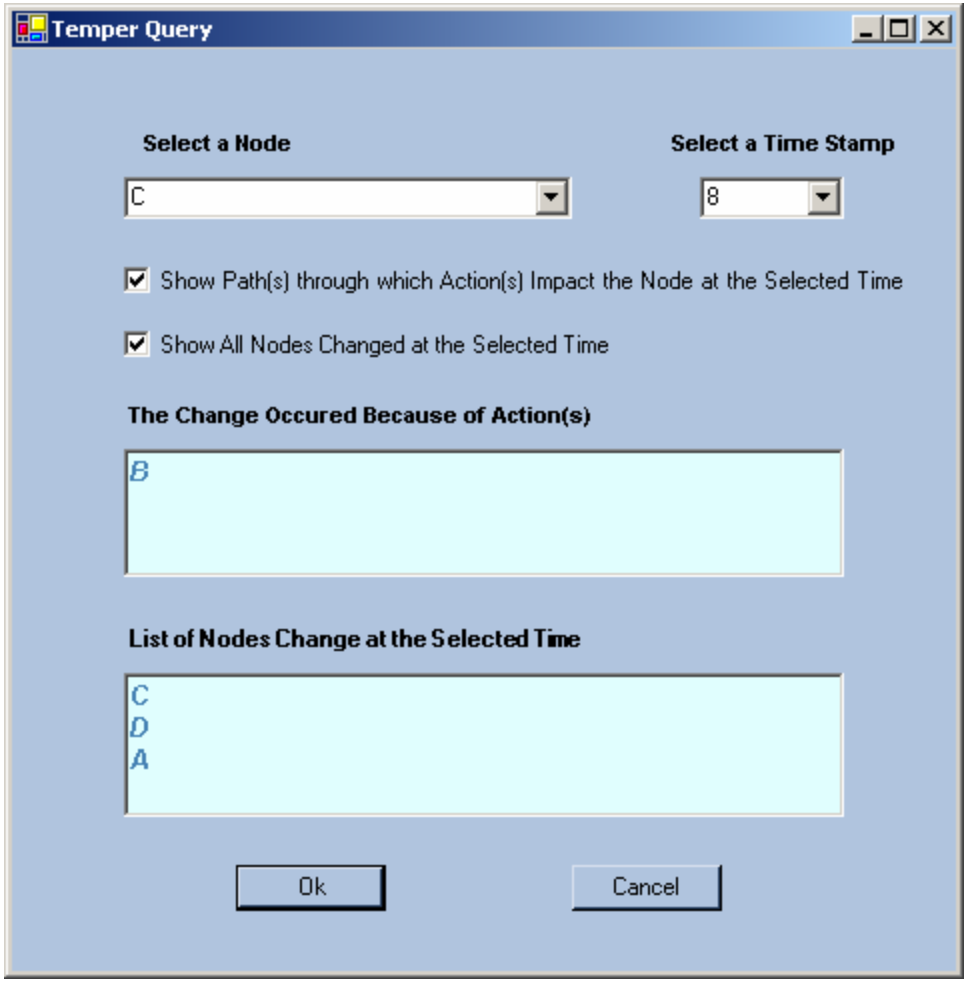
Action F is taken (or takes place) at time **7**

Action B is taken at time **1**

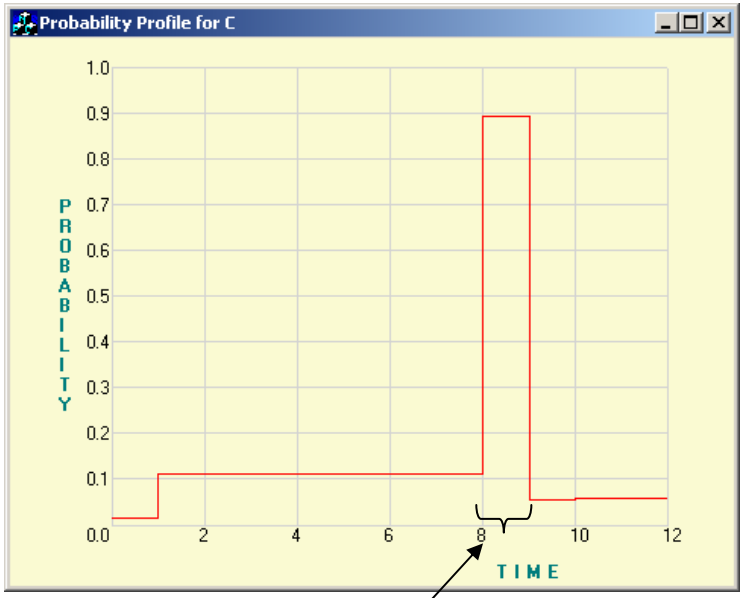


Temporal Analysis

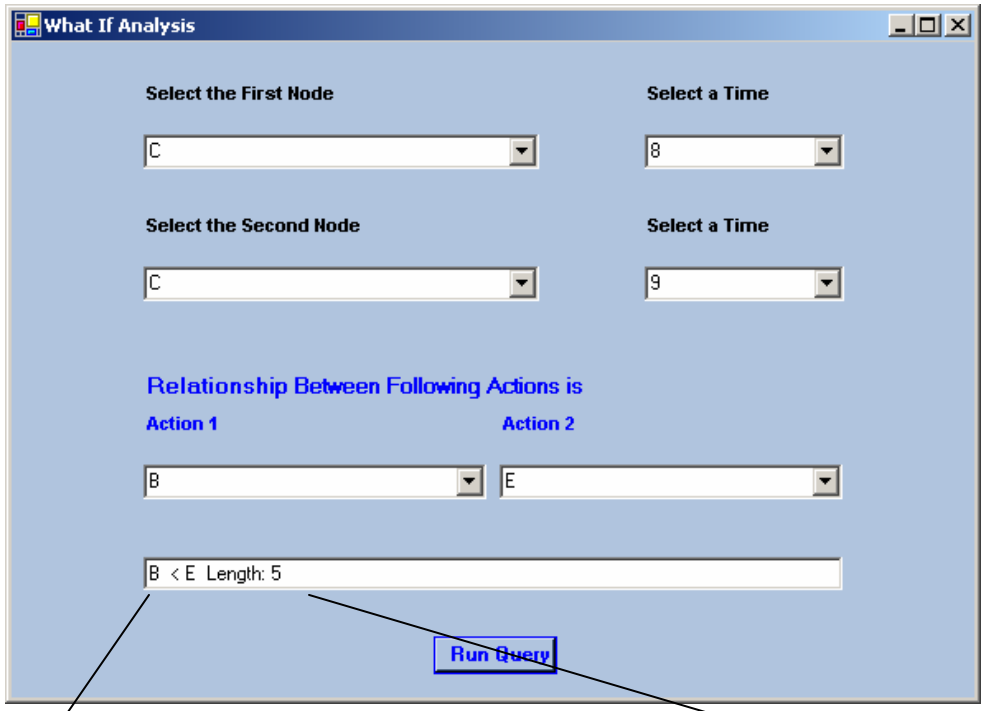




Temporal Analysis

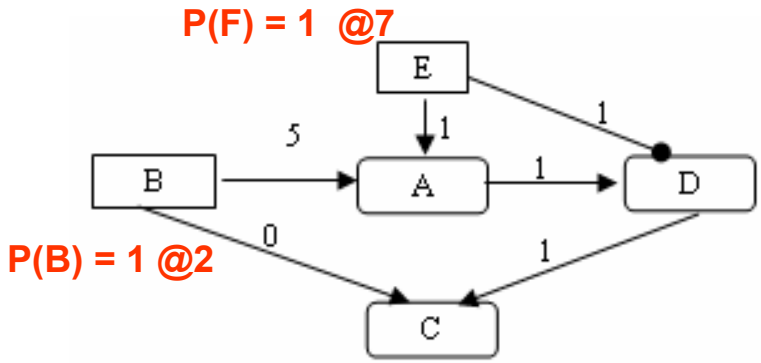


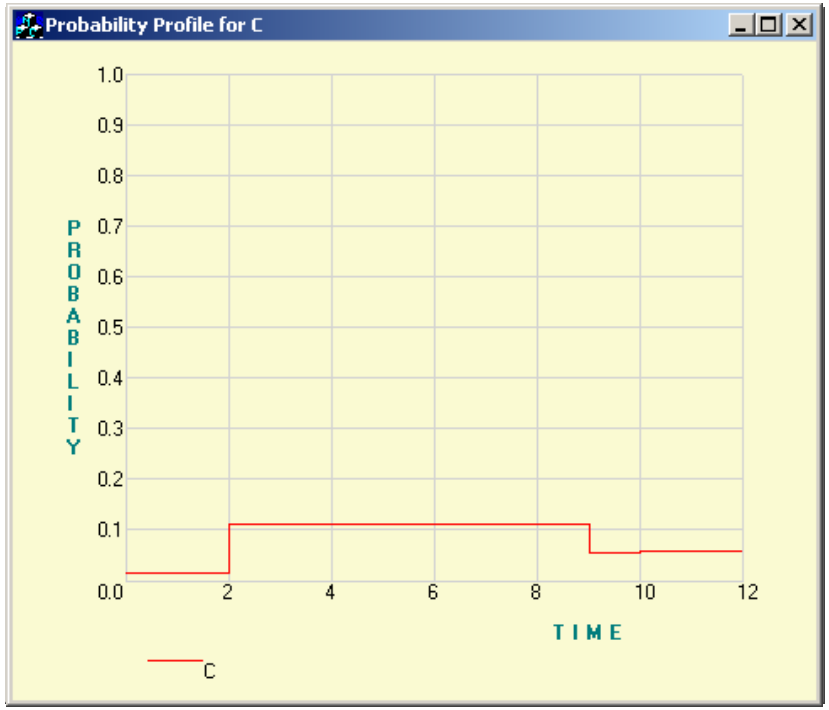
What needs to be done in order to combine the impacts at time 8 and 9?



B must be executed 5 time units Before E

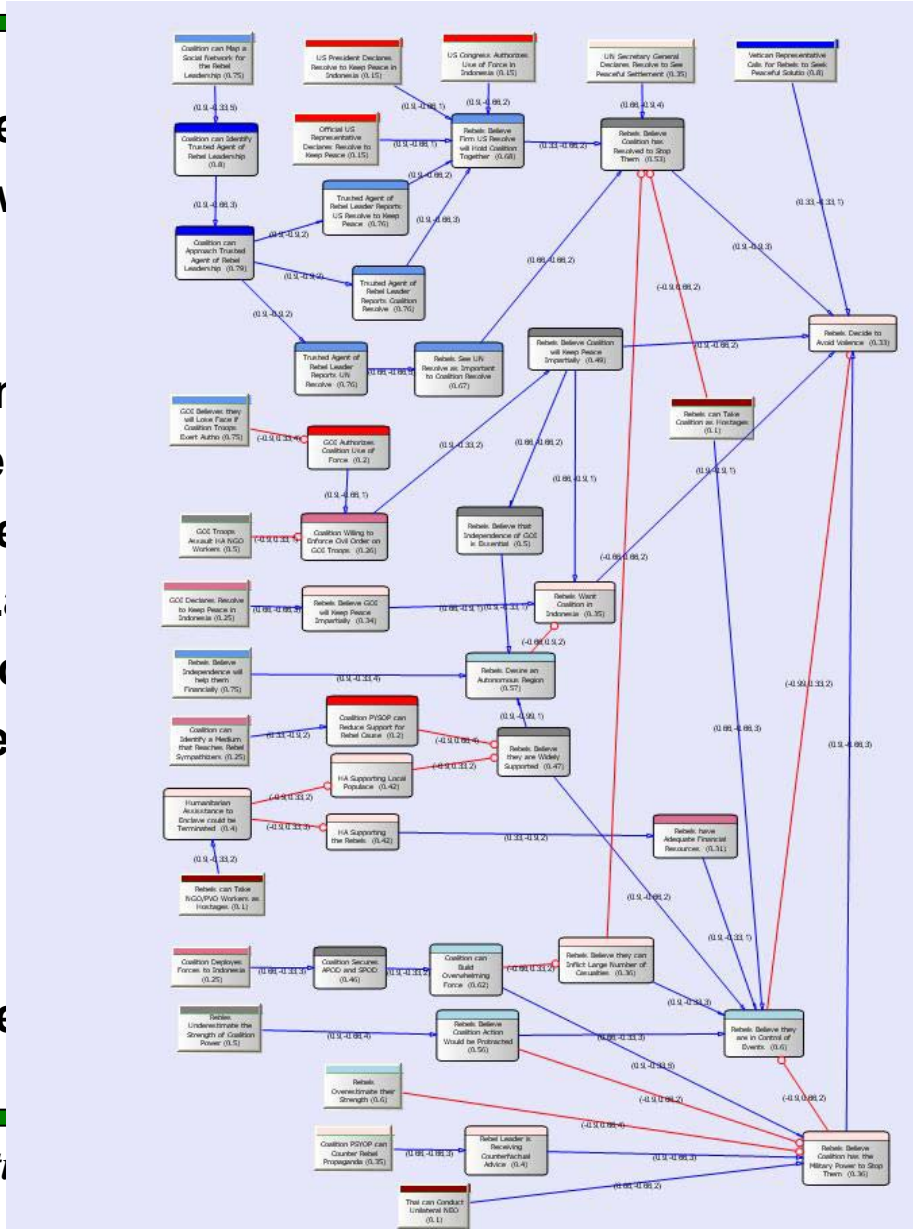
Temporal Analysis

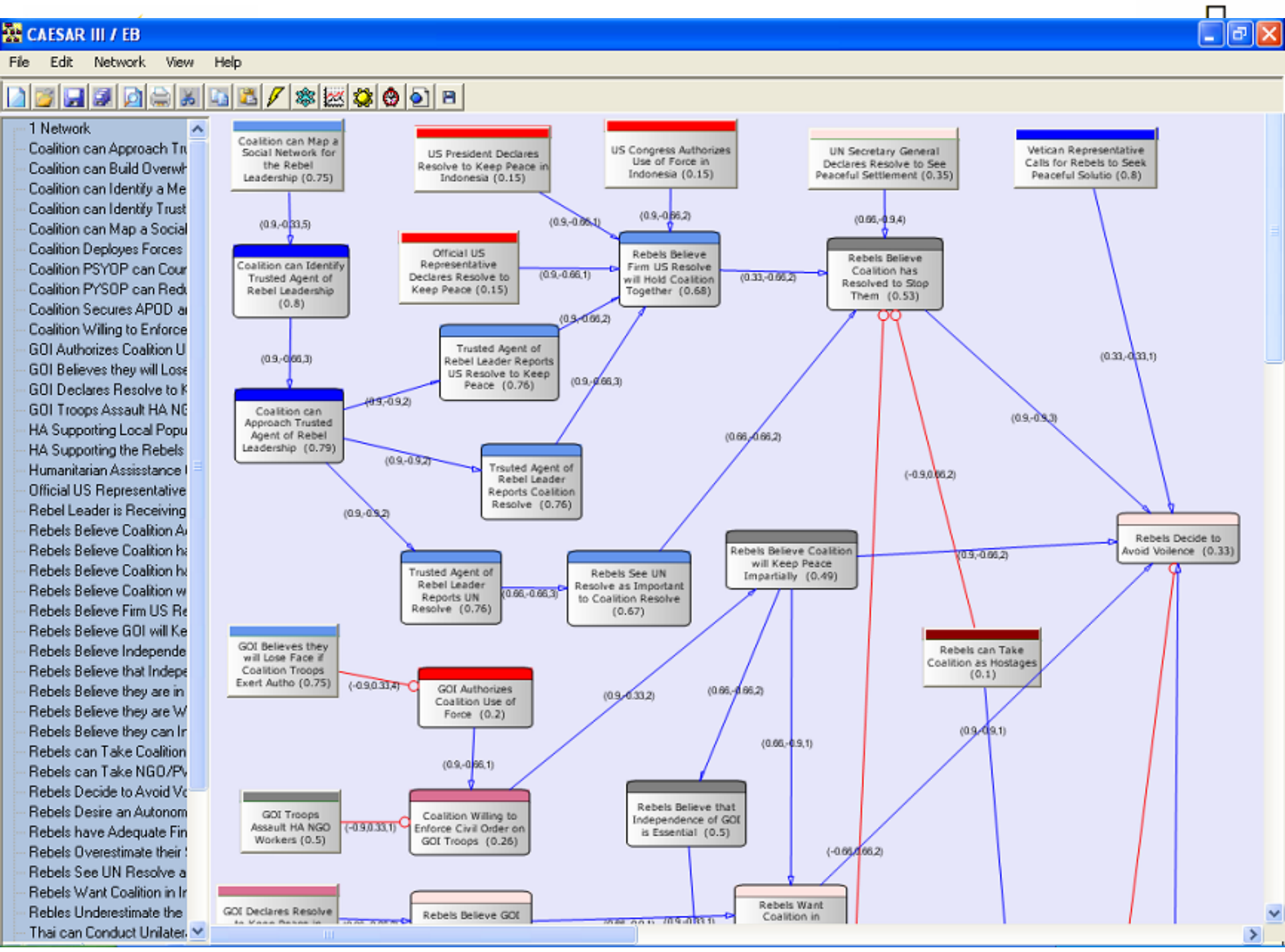




Application

- East Timor Model Presented in Wage
- A Plausible but Fictitious Scenario w Potential Use of Formalism
- The Scenario:
  - Internal Political Instabilities in Ir
  - Ethnic Tensions Among Multiple
  - Conflict Between a Minority Rebe
  - Rebels Securing an Enclave of L
  - Tension Between Local Populati
  - Role of Humanitarian Assistance
  - Role of Coalition Forces
  - …
- The Actionable Events:
  - Potential Coalition, UN, and Rebe




CAESAR III / EB
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Coalition can Approach Tr
Coalition can Build Overwh
Coalition can Identify a Me
Coalition can Identify Trust
Coalition can Map a Social
Coalition Deployes Forces
Coalition PSYOP can Cour
Coalition PYSOP can Redu
Coalition Secures APOD a
Coalition Willing to Enforce
GOI Authorizes Coalition U
GOI Believes they will Lose
GOI Declares Resolve to K
GOI Troops Assault HA NG
HA Supporting Local Popu
HA Supporting the Rebels
Humanitarian Assisstance
Official US Representative
Rebel Leader is Receiving
Rebels Believe Coalition A
Rebels Believe Coalition ha
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Rebels Believe Firm US Re
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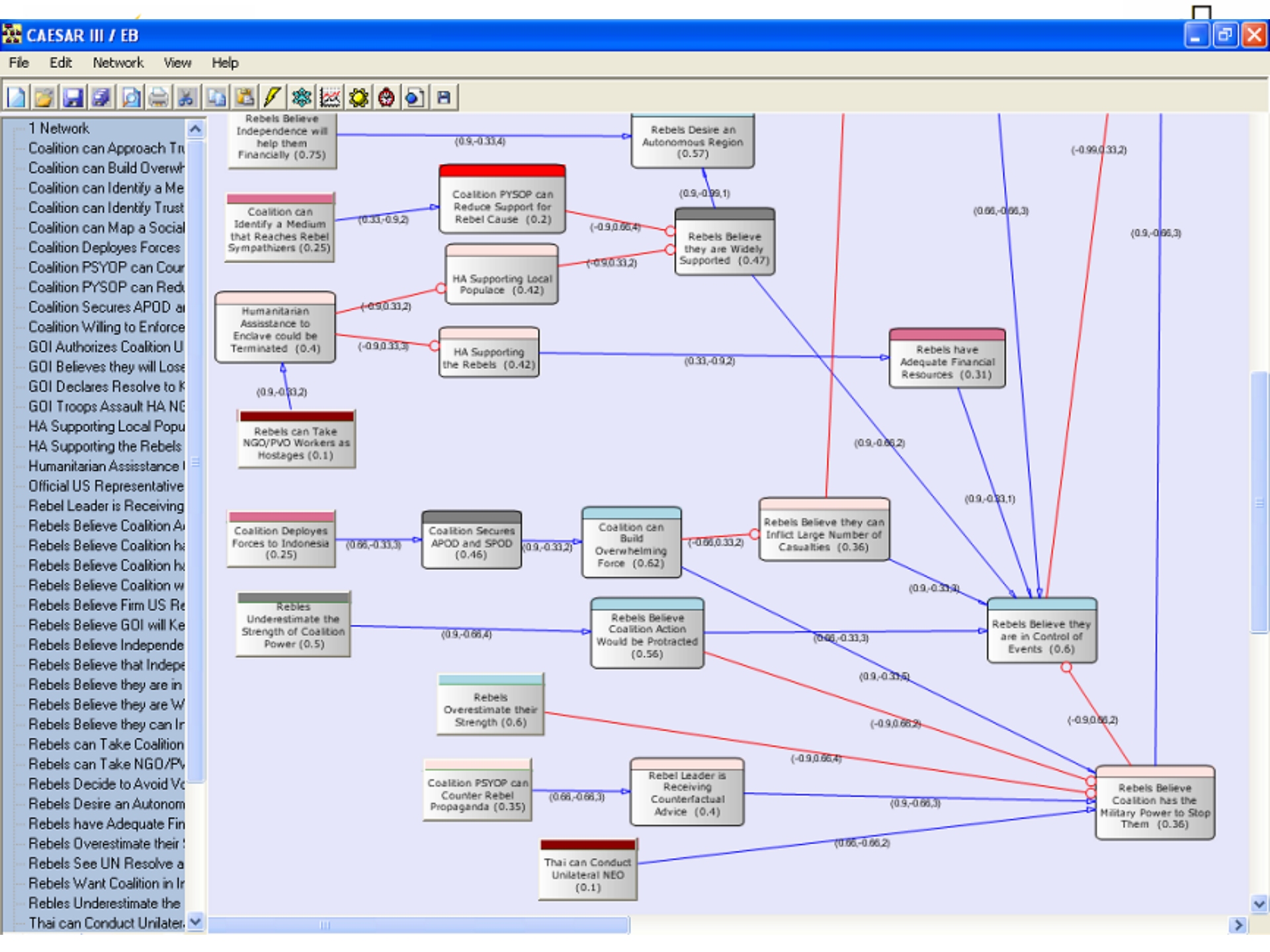
Rebels can Take Coalition
Rebels can Take NGO/PV
Rebels Decide to Avoid Vo
Rebels Desire an Autonom
Rebels have Adequate Fin
Rebels Overestimate their
Rebels See UN Resolve a
Rebels Want Coalition in Ir
Rebles Underestimate the
Thai can Conduct Unilater
Coalition can Map a Social Network for the Rebel Leadership (0.75)
US President Declares Resolve to Keep Peace in Indonesia (0.15)
US Congress Authorizes Use of Force in Indonesia (0.15)
UN Secretary General Declares Resolve to See Peaceful Settlement (0.35)
Vetican Representative Calls for Rebels to Seek Peaceful Solutio (0.8)
(0.9,-0.33,5)
(0.9,-0.66,1)
(0.9,-0.66,2)
(0.66,-0.9,4)
Coalition can Identify Trusted Agent of Rebel Leadership (0.8)
Official US Representative Declares Resolve to Keep Peace (0.15)
Rebels Believe Firm US Resolve will Hold Coalition Together (0.68)
(0.9,-0.66,1)
(0.33,-0.66,2)
Rebels Believe Coalition has Resolved to Stop Them (0.53)
(0.9,-0.66,2)
(0.9,-0.66,3)
Trusted Agent of Rebel Leader Reports US Resolve to Keep Peace (0.76)
(0.33,-0.33,1)
(0.9,-0.66,3)
(0.9,-0.9,2)
Coalition can Approach Trusted Agent of Rebel Leadership (0.79)
(0.9,-0.9,3)
(0.66,-0.66,2)
(0.9,-0.9,2)
Trsuted Agent of Rebel Leader Reports Coalition Resolve (0.76)
(-0.9,0.66,2)
(0.9,-0.9,2)
Rebels Decide to Avoid Voilence (0.33)
Trusted Agent of Rebel Leader Reports UN Resolve (0.76)
(0.66,-0.66,3)
Rebels See UN Resolve as Important to Coalition Resolve (0.67)
Rebels Believe Coalition will Keep Peace Impartially (0.49)
(0.9,-0.66,2)
GOI Believes they will Lose Face if Coalition Troops Exert Autho (0.75)
Rebels can Take Coalition as Hostages (0.1)
(-0.9,0.33,4)
GOI Authorizes Coalition Use of Force (0.2)
(0.9,-0.33,2)
(0.66,-0.66,2)
(0.9,-0.9,1)
(0.9,-0.66,1)
GOI Troops Assault HA NGO Workers (0.5)
(-0.9,0.33,1)
Coalition Willing to Enforce Civil Order on GOI Troops (0.26)
Rebels Believe that Independence of GOI is Essential (0.5)
(-0.66,0.66,2)
GOI Declares Resolve
Rebels Believe GOI
Rebels Want Coalition in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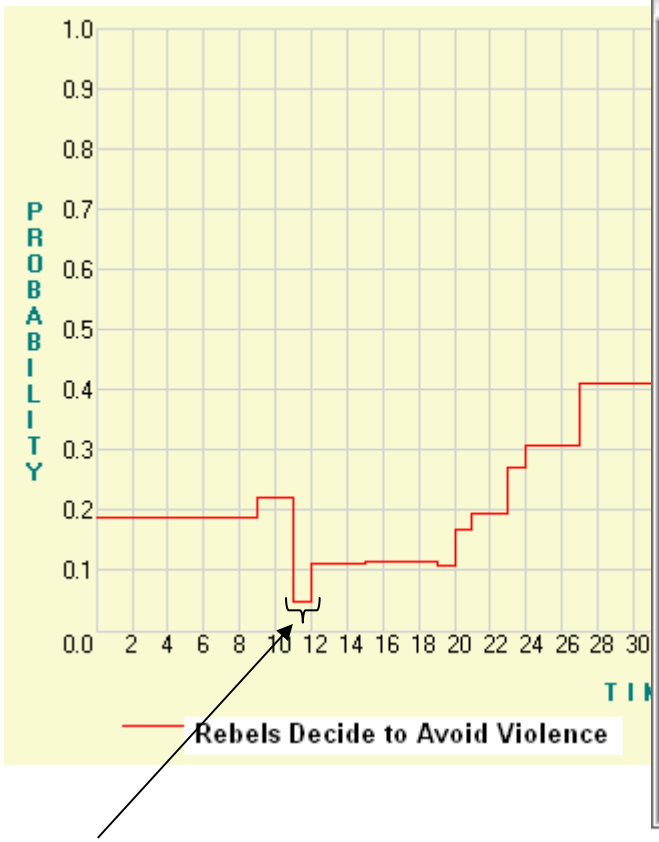
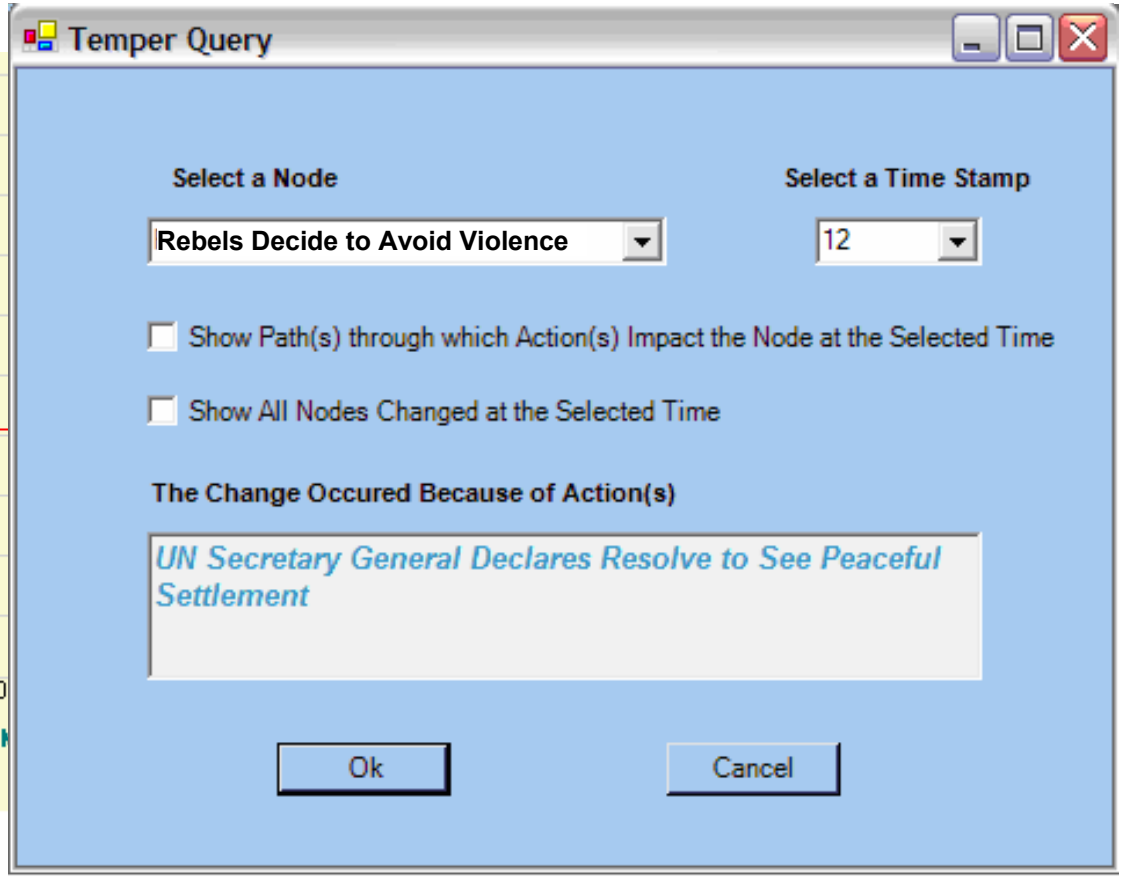
Rebels have Adequate Fin
Rebels Overestimate their
Rebels See UN Resolve a
Rebels Want Coalition in Ir
Rebles Underestimate the
Thai can Conduct Unilater
Rebels Believe Independence will help them Financially (0.75)
(0.9,-0.33,4)
Rebels Desire an Autonomous Region (0.57)
(0.9,-0.99,1)
Coalition can Identify a Medium that Reaches Rebel Sympathizers (0.25)
(0.33,-0.9,2)
Coalition PYSOP can Reduce Support for Rebel Cause (0.2)
(-0.9,0.66,4)
Rebels Believe they are Widely Supported (0.47)
(-0.99,0.33,2)
(0.66,-0.66,3)
(0.9,-0.66,3)
HA Supporting Local Populace (0.42)
(-0.9,0.33,2)
Humanitarian Assisstance to Enclave could be Terminated (0.4)
(-0.9,0.33,2)
(-0.9,0.33,3)
HA Supporting the Rebels (0.42)
(0.33,-0.9,2)
Rebels have Adequate Financial Resources (0.31)
(0.9,-0.33,2)
Rebels can Take NGO/PVO Workers as Hostages (0.1)
(0.9,-0.66,2)
(0.9,-0.33,1)
Coalition Deployes Forces to Indonesia (0.25)
(0.66,-0.33,3)
Coalition Secures APOD and SPOD (0.46)
(0.9,-0.33,2)
Coalition can Build Overwhelming Force (0.62)
(-0.66,0.33,2)
Rebels Believe they can Inflict Large Number of Casualties (0.36)
(0.9,-0.33,3)
Rebles Underestimate the Strength of Coalition Power (0.5)
(0.9,-0.66,4)
Rebels Believe Coalition Action Would be Protracted (0.56)
(0.66,-0.33,3)
Rebels Believe they are in Control of Events (0.6)
(0.9,-0.33,6)
(-0.9,0.66,2)
Rebels Overestimate their Strength (0.6)
(-0.9,0.66,2)
(-0.9,0.66,4)
Coalition PSYOP can Counter Rebel Propaganda (0.35)
(0.66,-0.66,3)
Rebel Leader is Receiving Counterfactual Advice (0.4)
(0.9,-0.66,3)
Rebels Believe Coalition has the Military Power to Stop Them (0.36)
Thai can Conduct Unilateral NEO (0.1)
(0.66,-0.66,2)

Application





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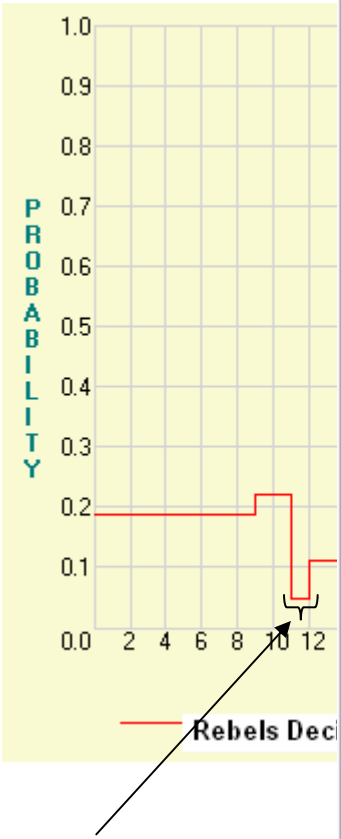
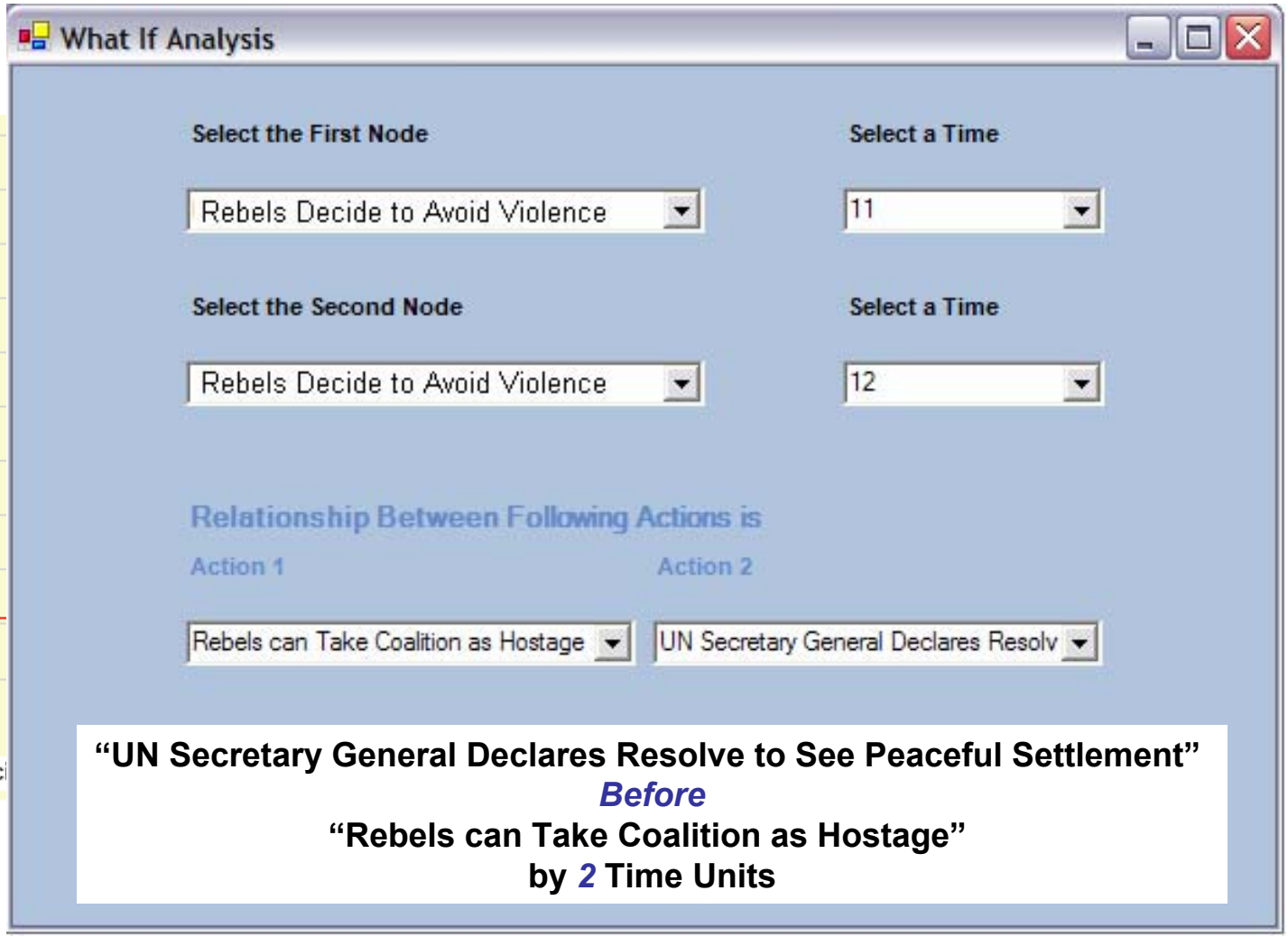
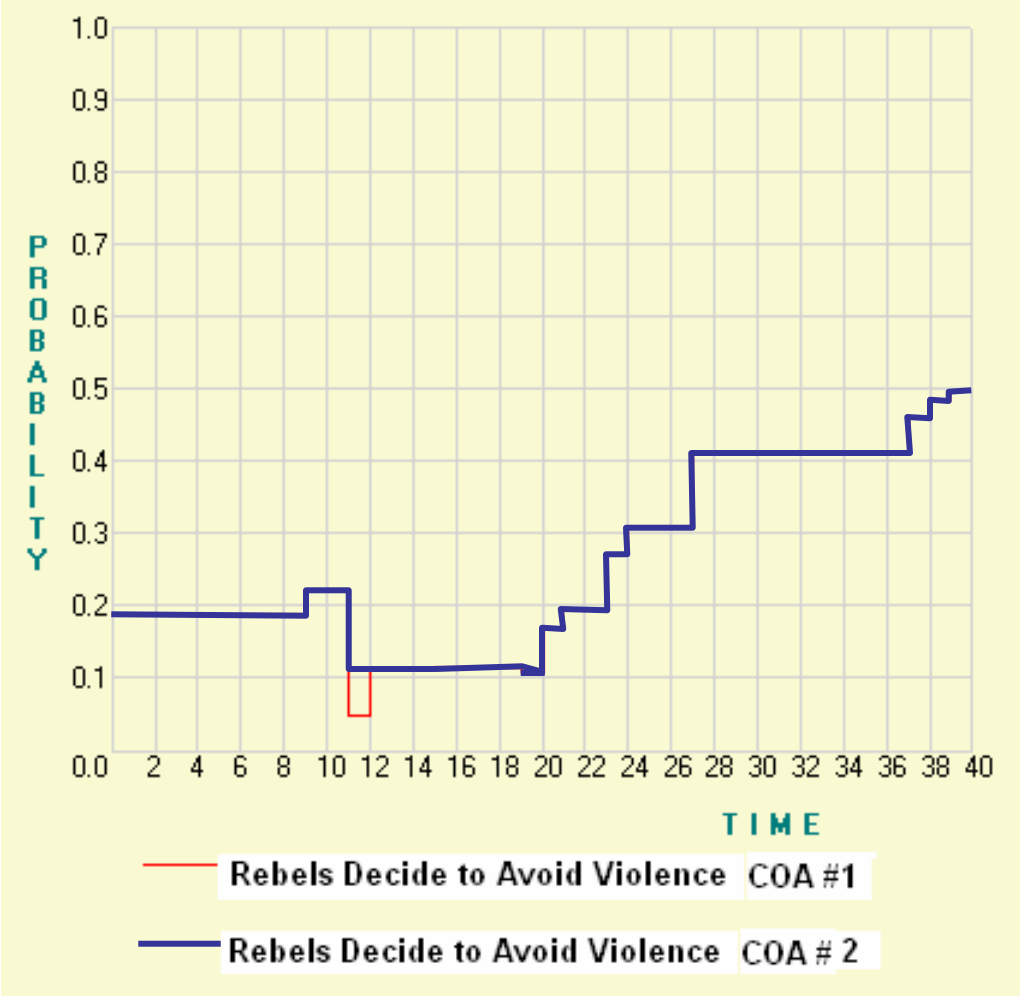




"UN Secretary General Declares Resolve to See Peaceful Settlement"
Before
"Rebels can Take Coalition as Hostage"
by *2* Time Units

Application



Conclusion

- **The Paper Presents a Tool for Assessment and Analysis of Courses of Action in a Timed Influence Net Model for Conducting Effects-Based Operations by:**
  - **Analyzing the Impact of Timing of Actions on the Likelihood of Desired/Undesired Effects**
  - **Fine-tuning Selected COAs for Generating Better Plans**
- **The Capability is Available in the Application *Pythia* Developed at the System Architectures Lab**