Bayesian Network Queries

CS161: Introduction to Artificial Intelligence

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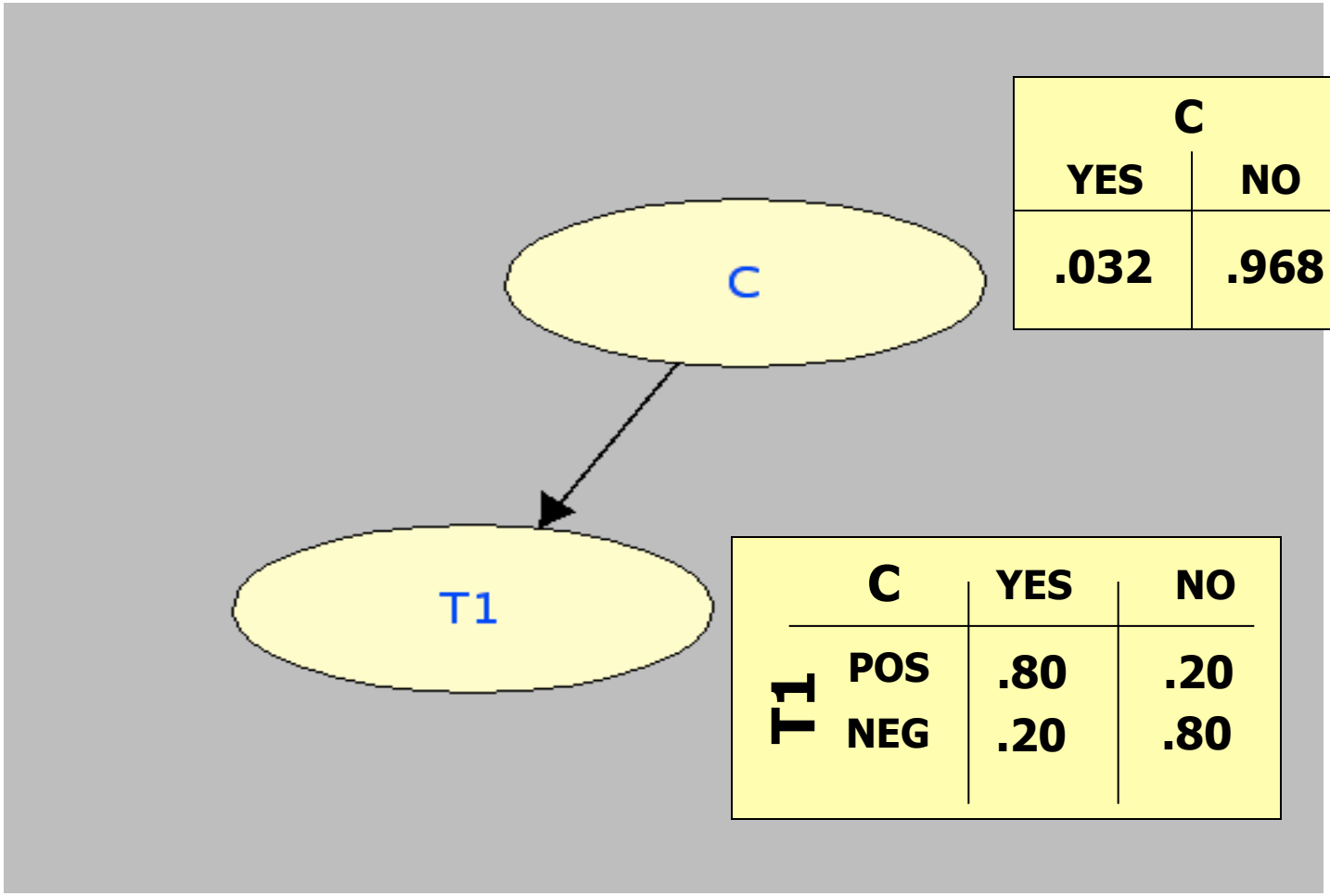
A Simple Problem

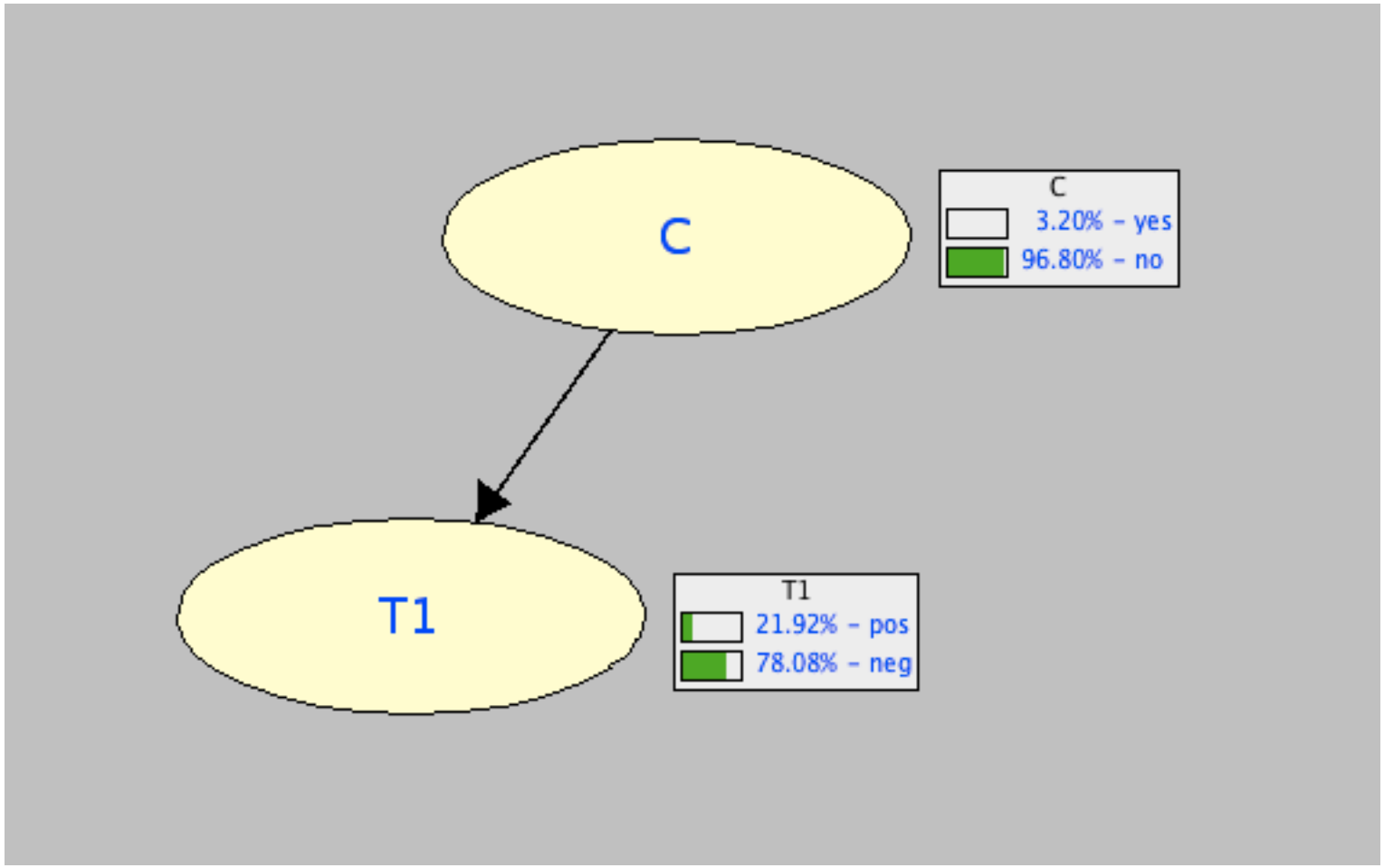
- Jack suspects having a medical condition which hits 3.2% of the population
- He takes a test that has a false positive/ negative rate of 20%
- The test comes out positive

- What's the probability that Jack has the condition?

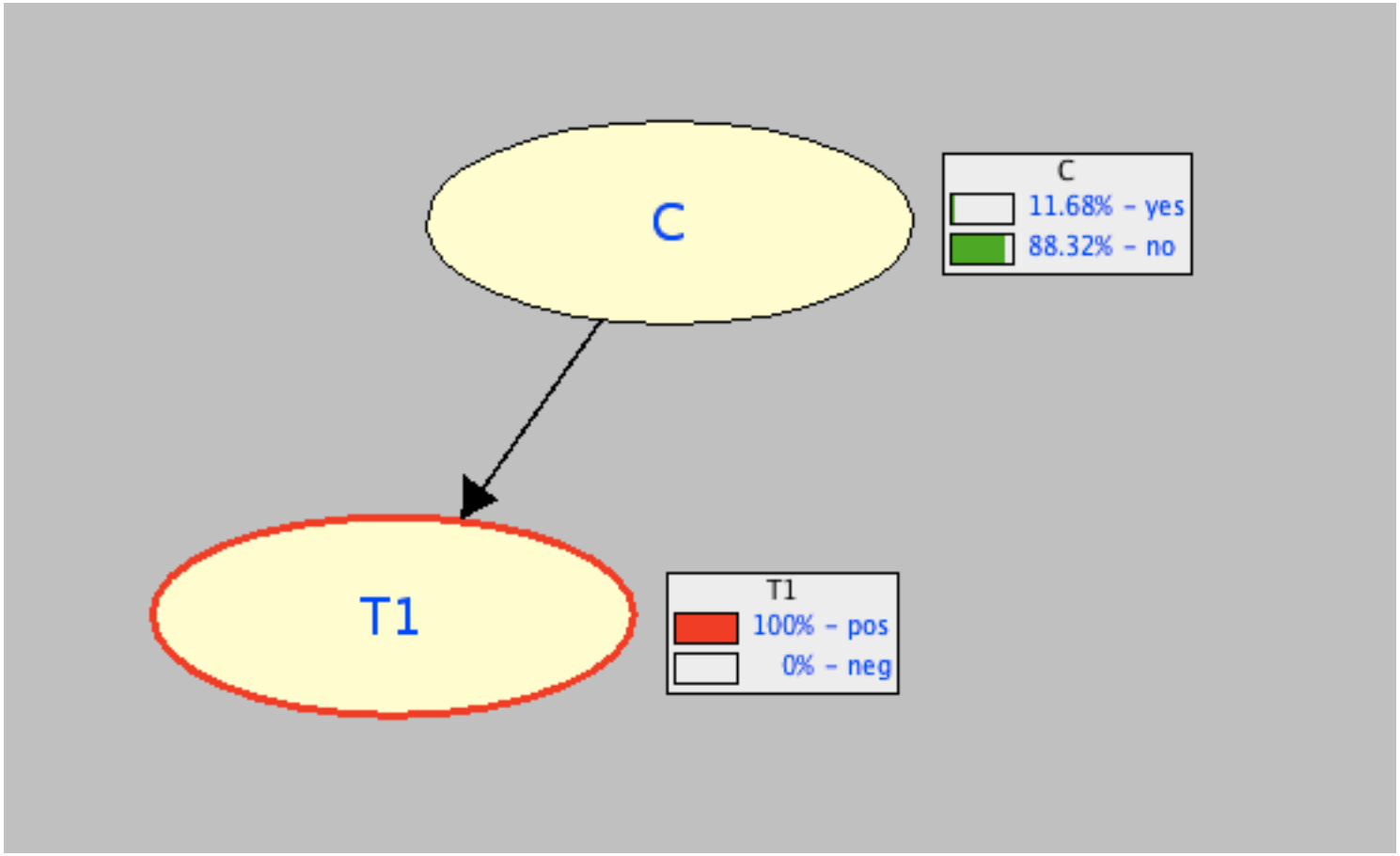
A Simple Network



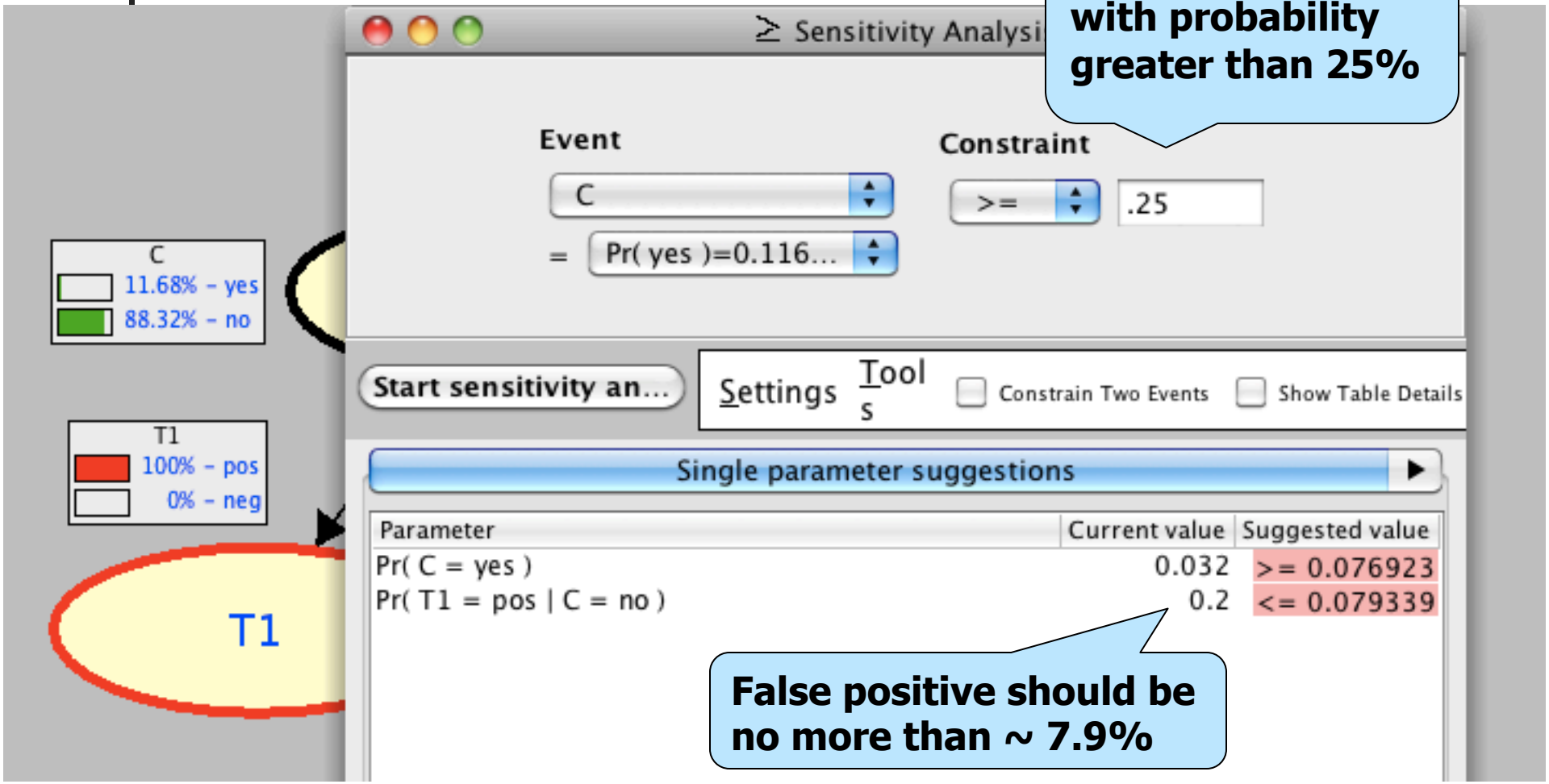
Prior Marginals



Posterior Marginals



Sensitivity Analysis

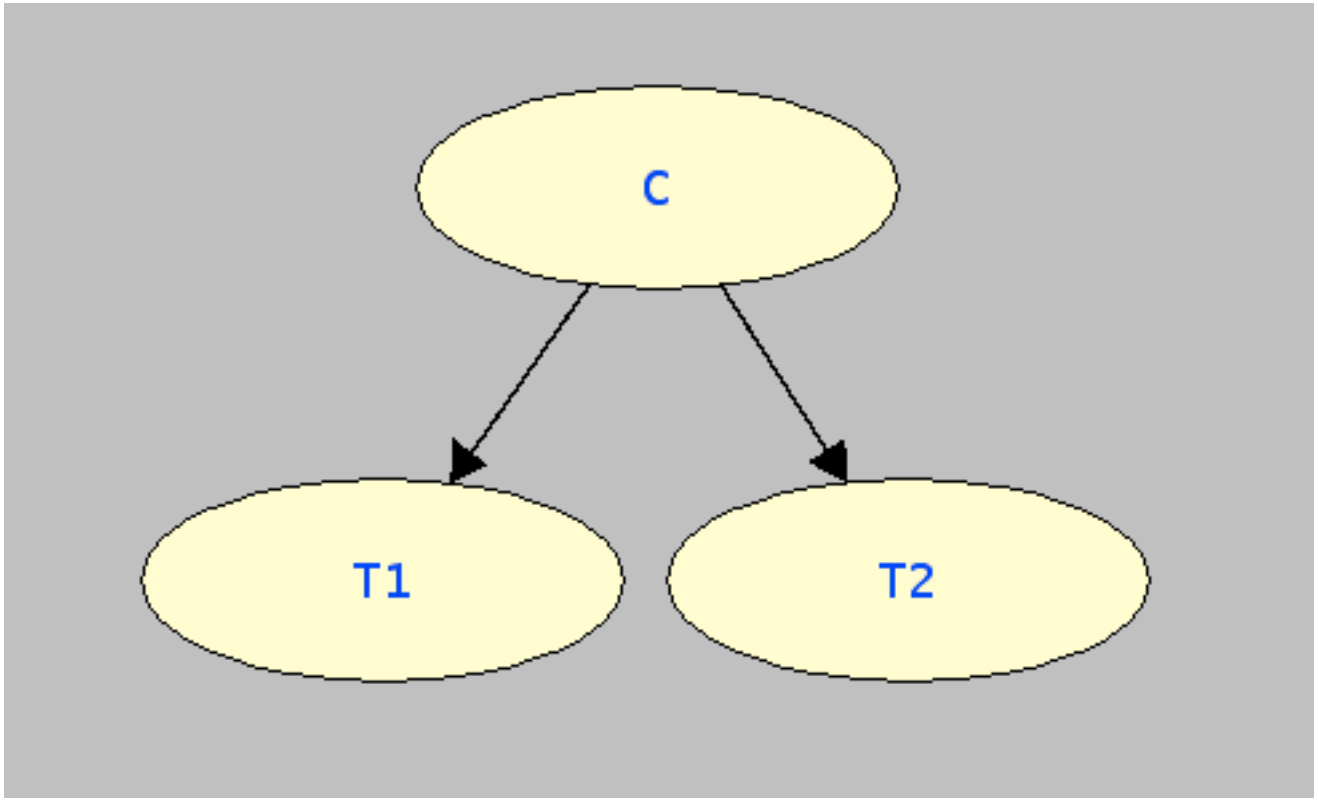


Another test

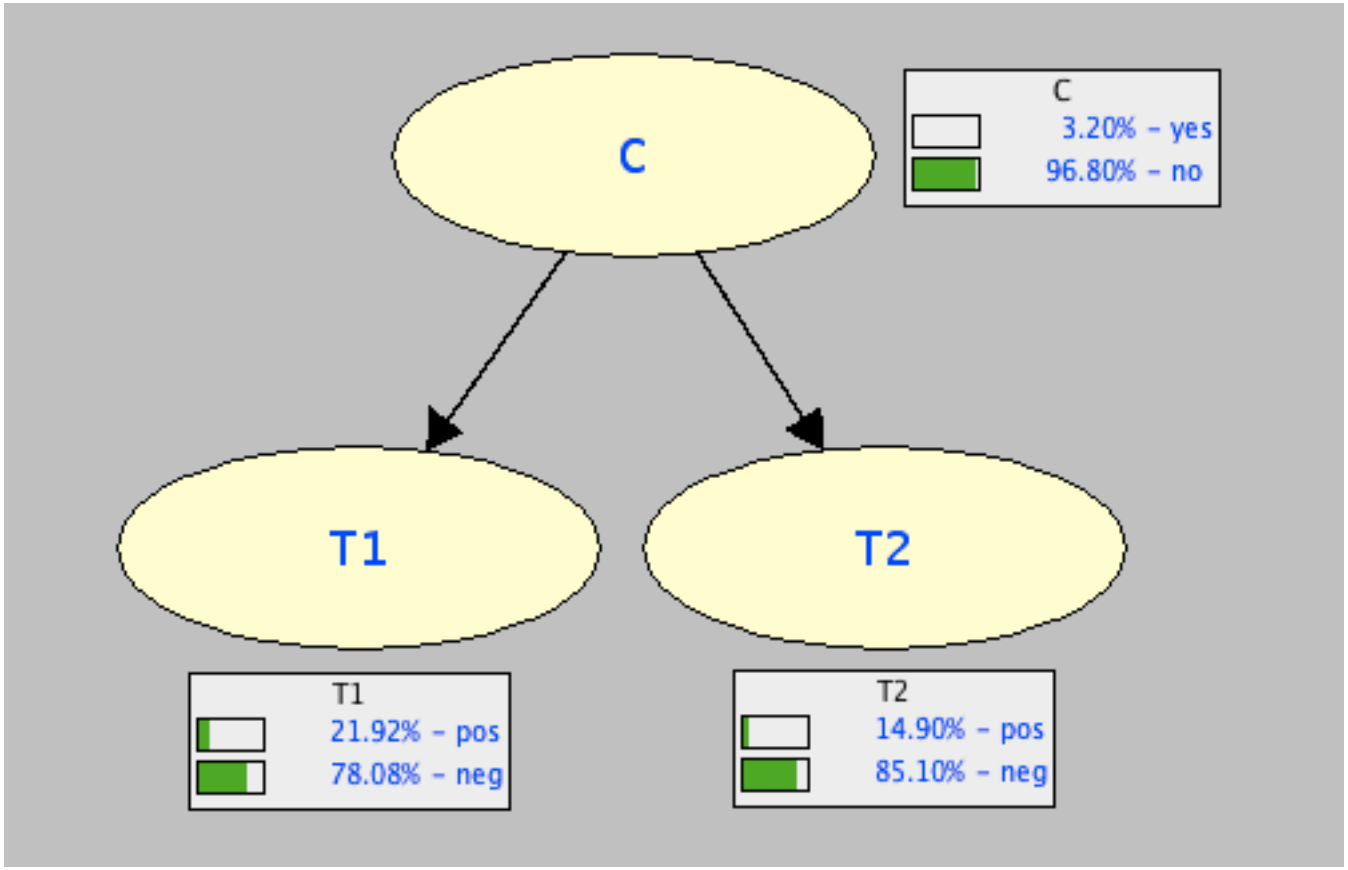
- Jack took another test that has a false positive/negative rate of 12.5%
- The test also came out positive

- What's the probability that Jack has the condition?

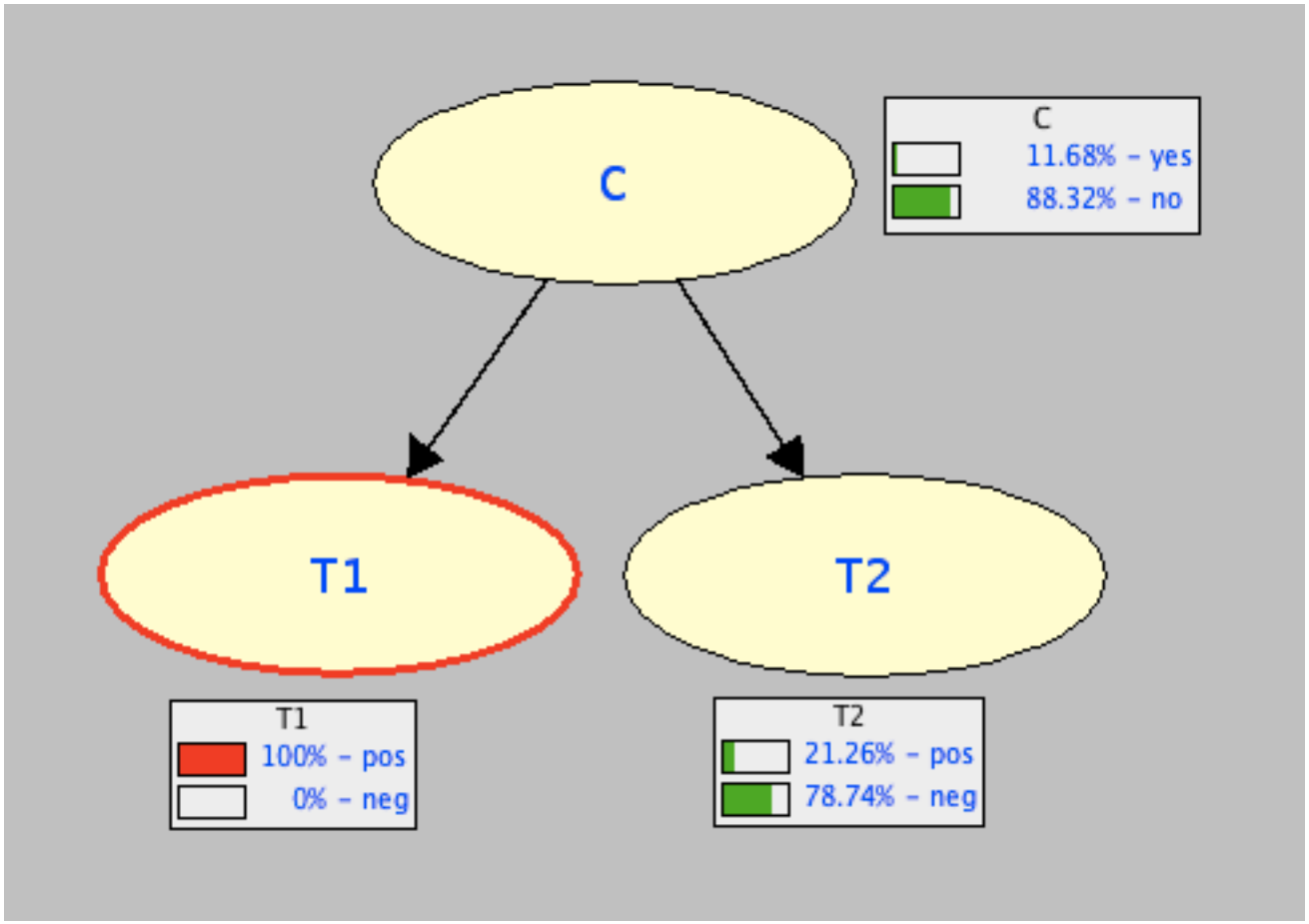
Another test



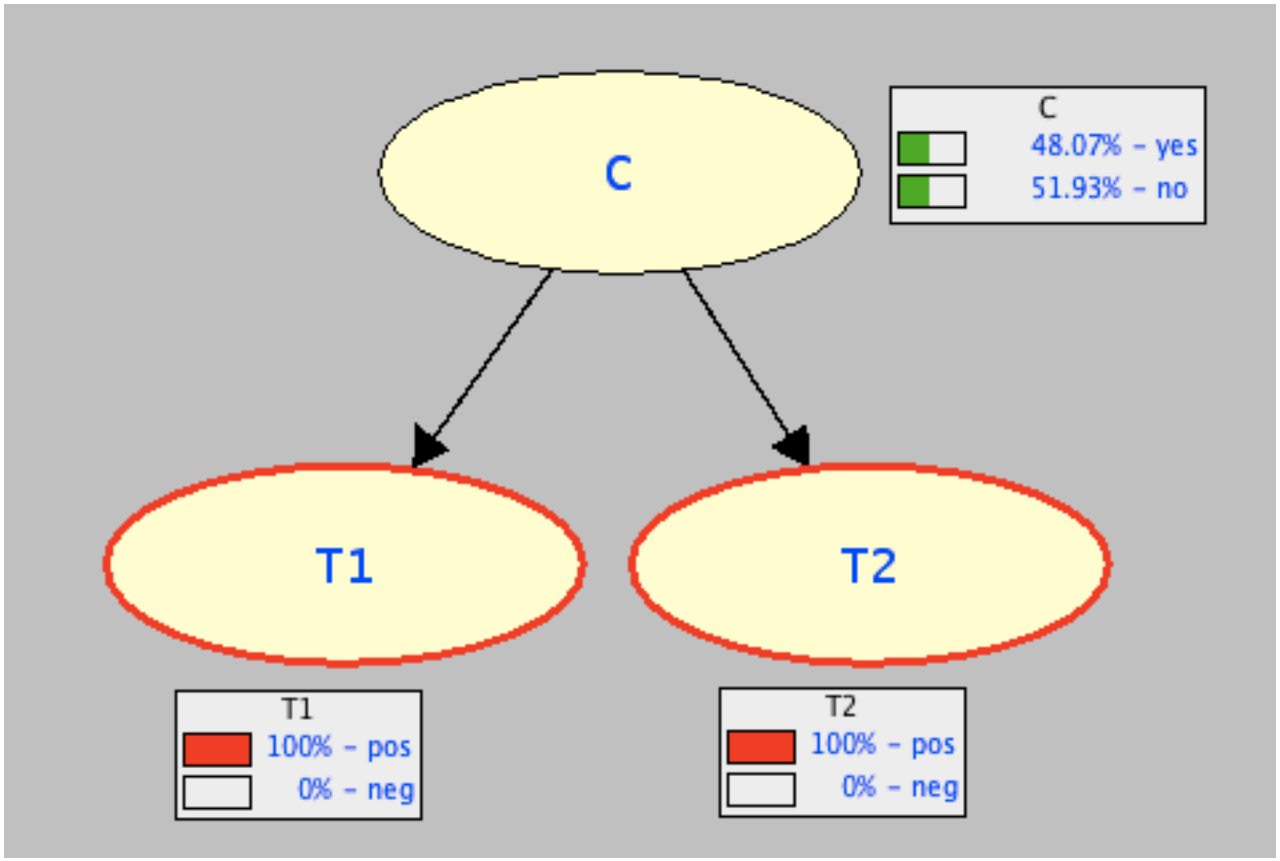
Another test



Another test

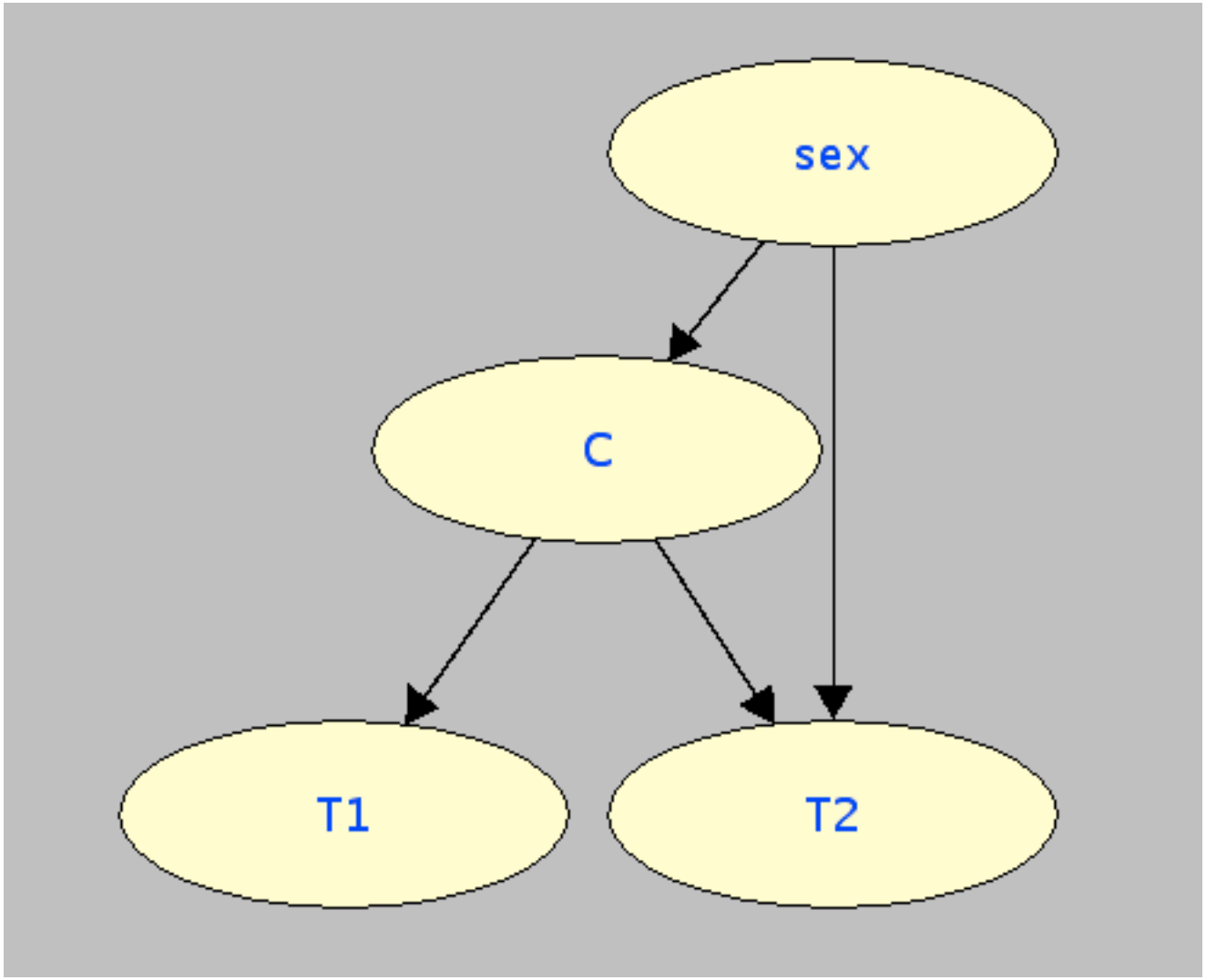


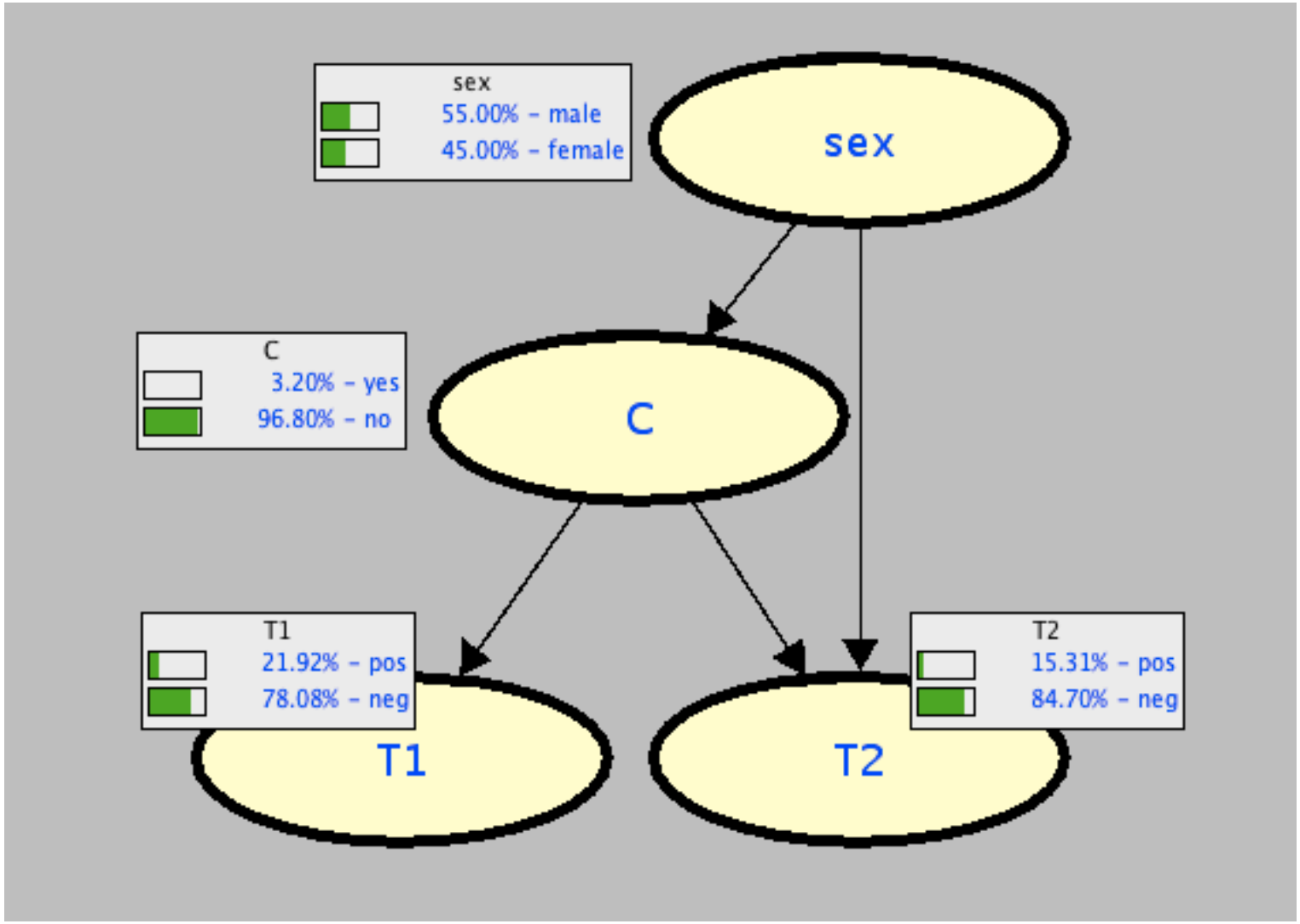
Another test



Introducing Gender

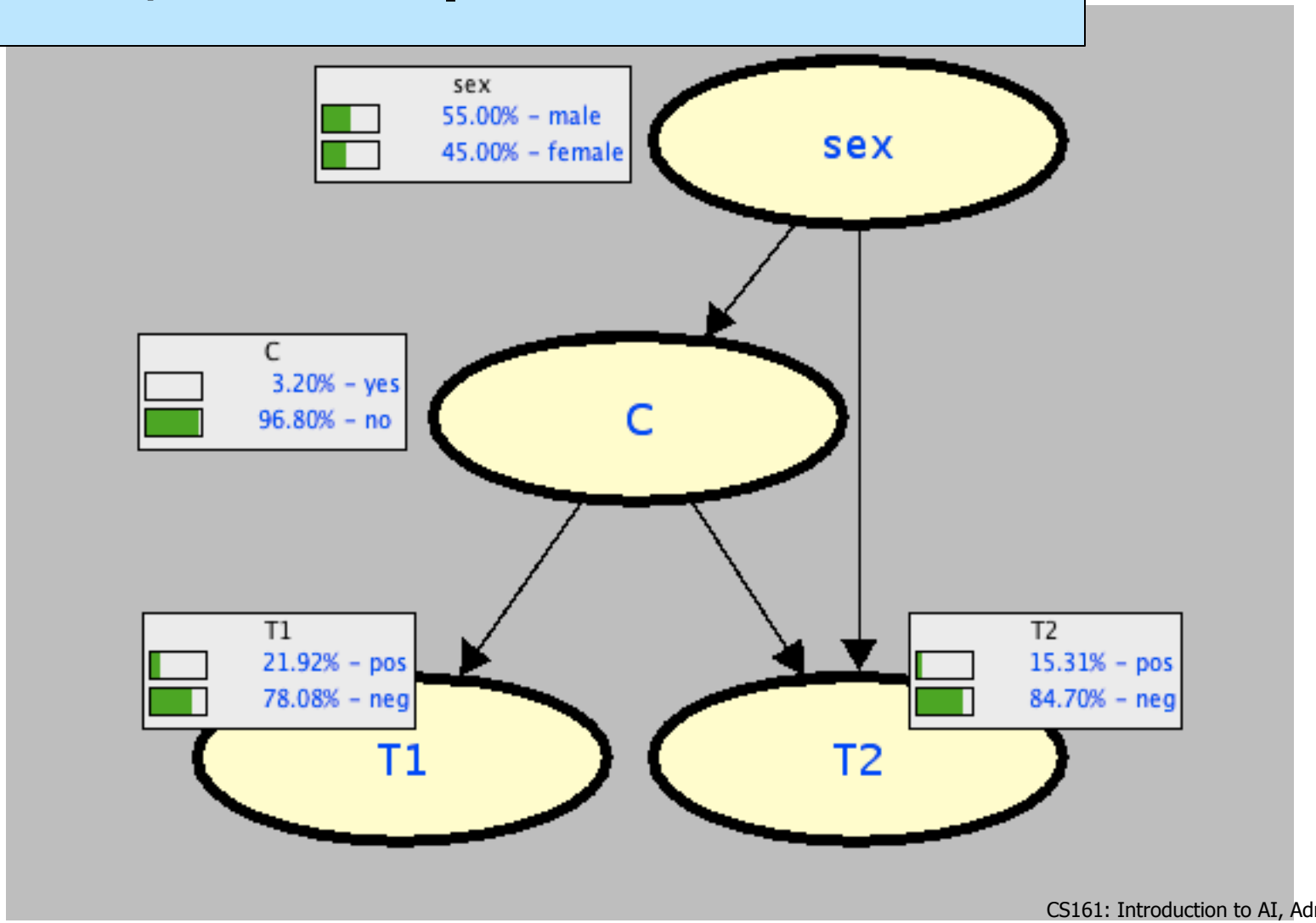
- The condition is more common in males (5%) than females (1%)
- The second test is more effective on females (…)

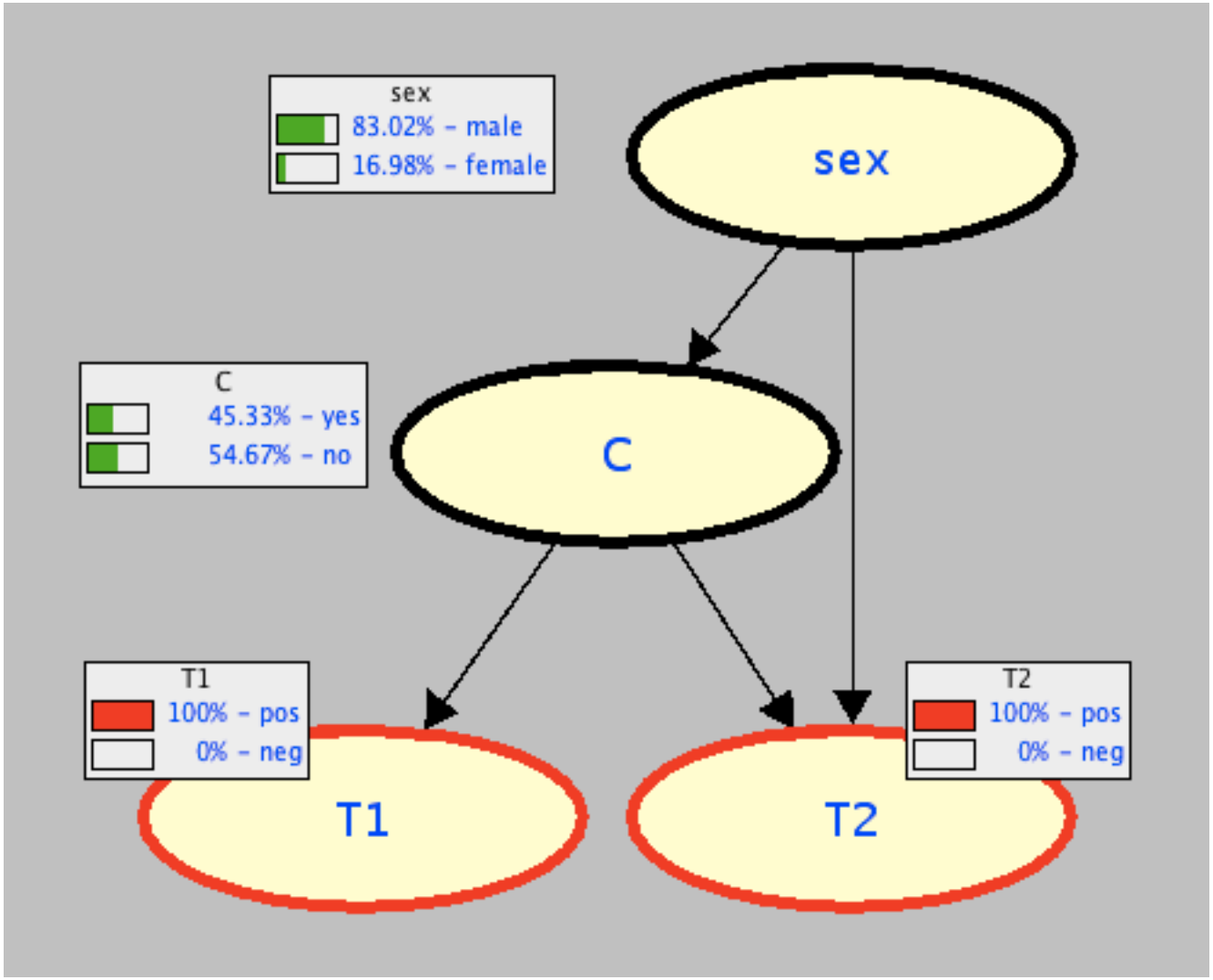

sex
C
T1
T2

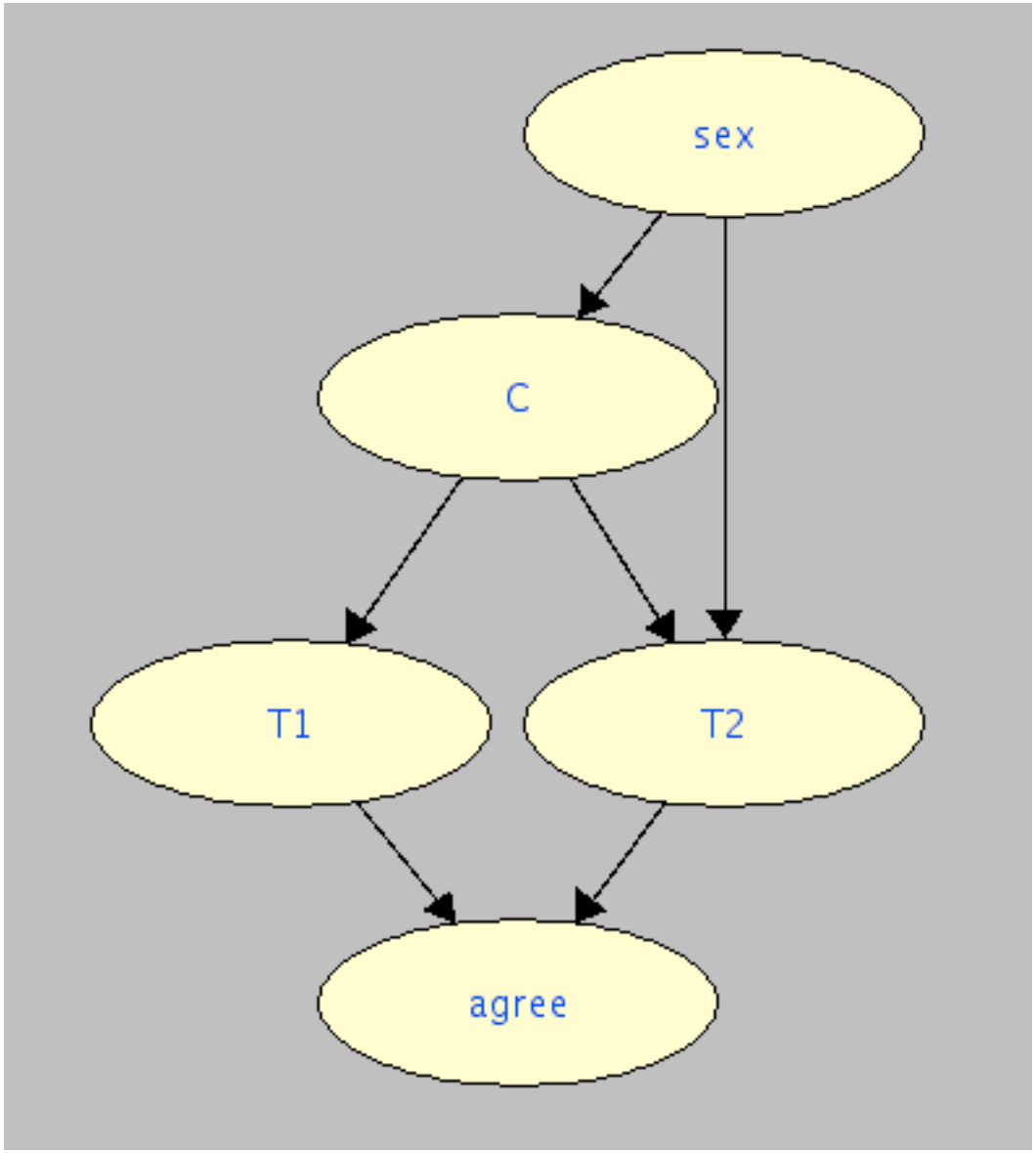

sex
55.00% - male
45.00% - female
sex
C
3.20% - yes
96.80% - no
C
T1
21.92% - pos
78.08% - neg
T1
T2
15.31% - pos
84.70% - neg
T2

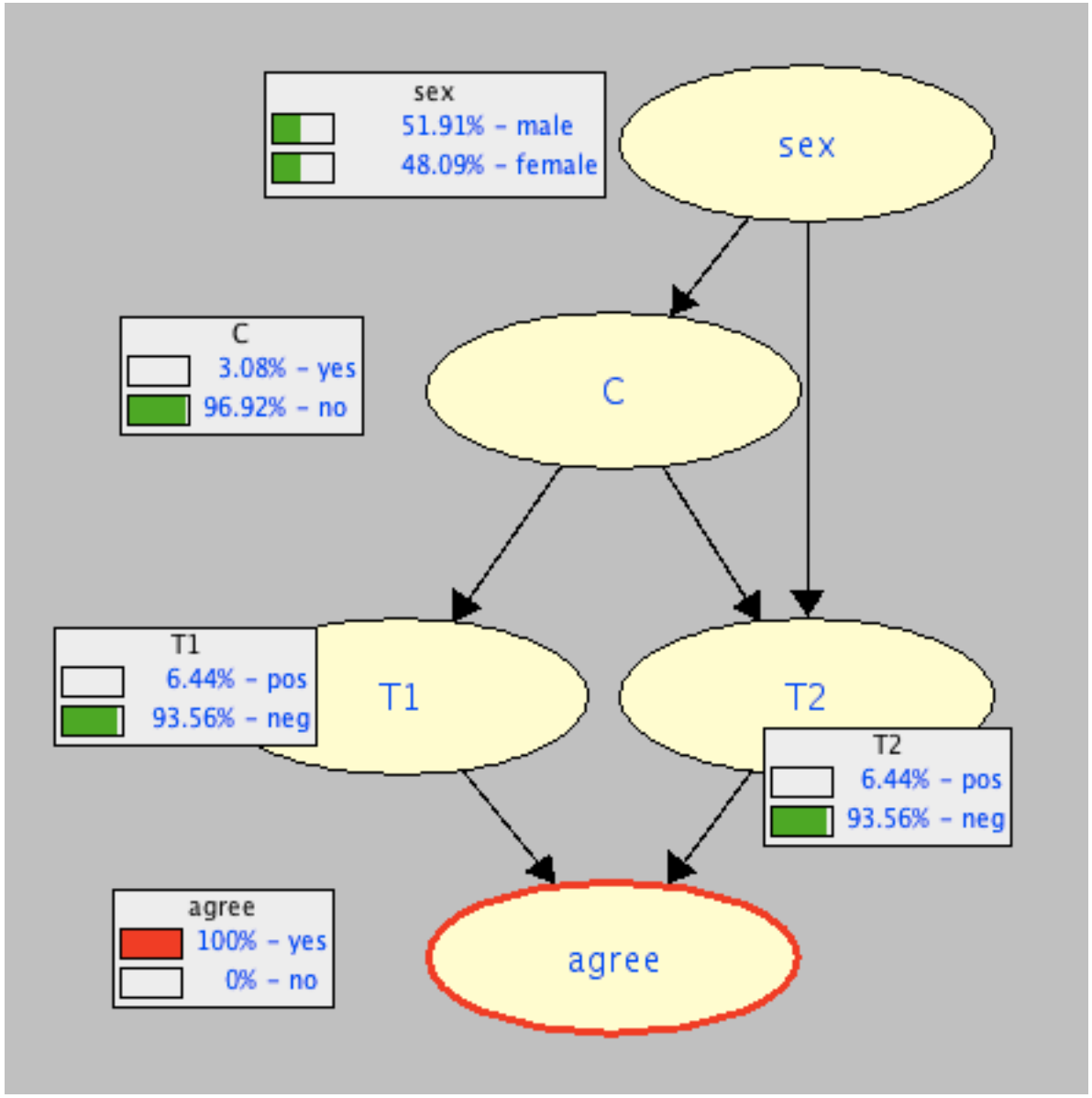
Independencies implied by network:

- Given C, T1 and T2 are independent
- Given C, T1 is independent of Sex

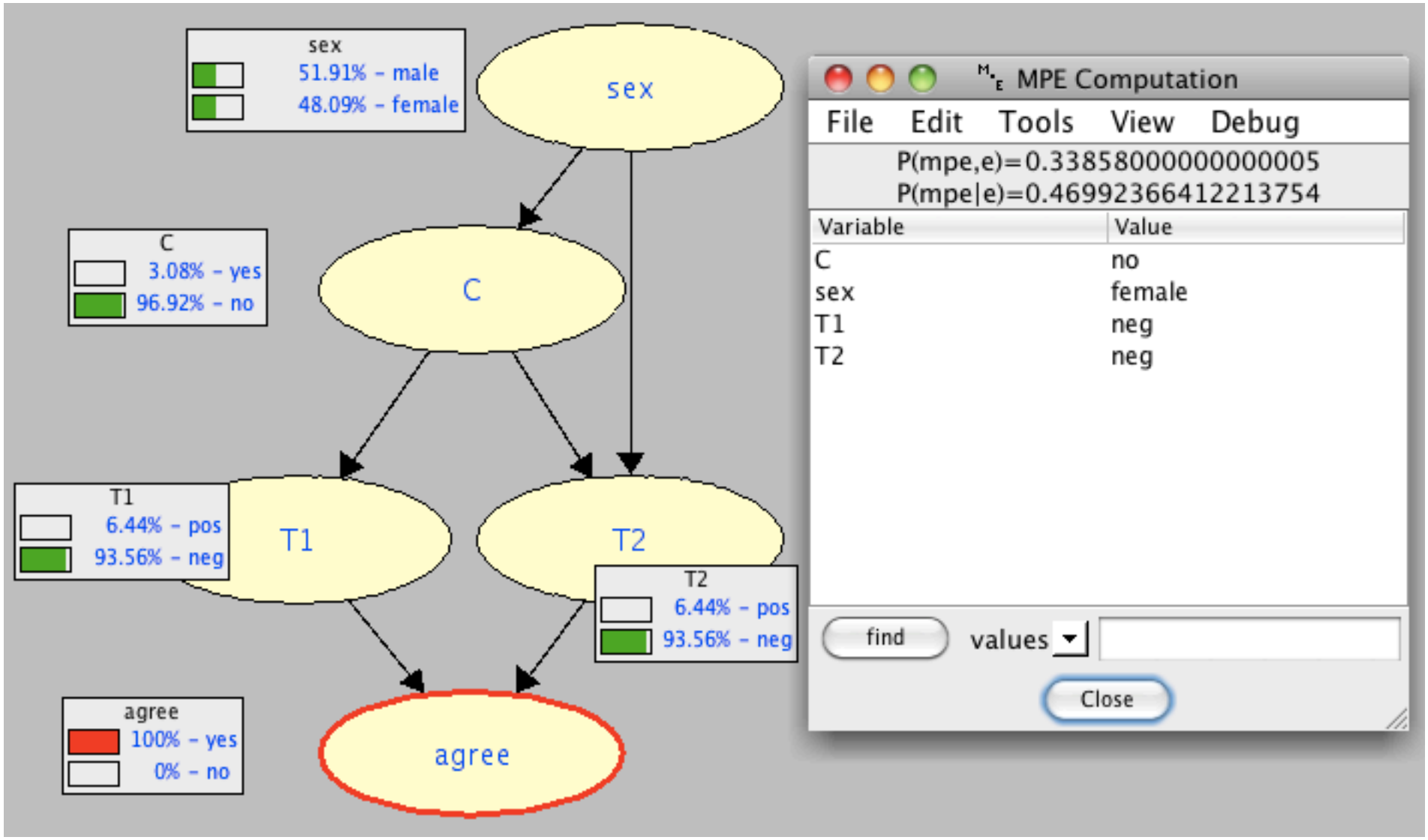



sex
83.02% - male
16.98% - female
sex
C
45.33% - yes
54.67% - no
C
T1
100% - pos
0% - neg
T1
T2
100% - pos
0% - neg
T2

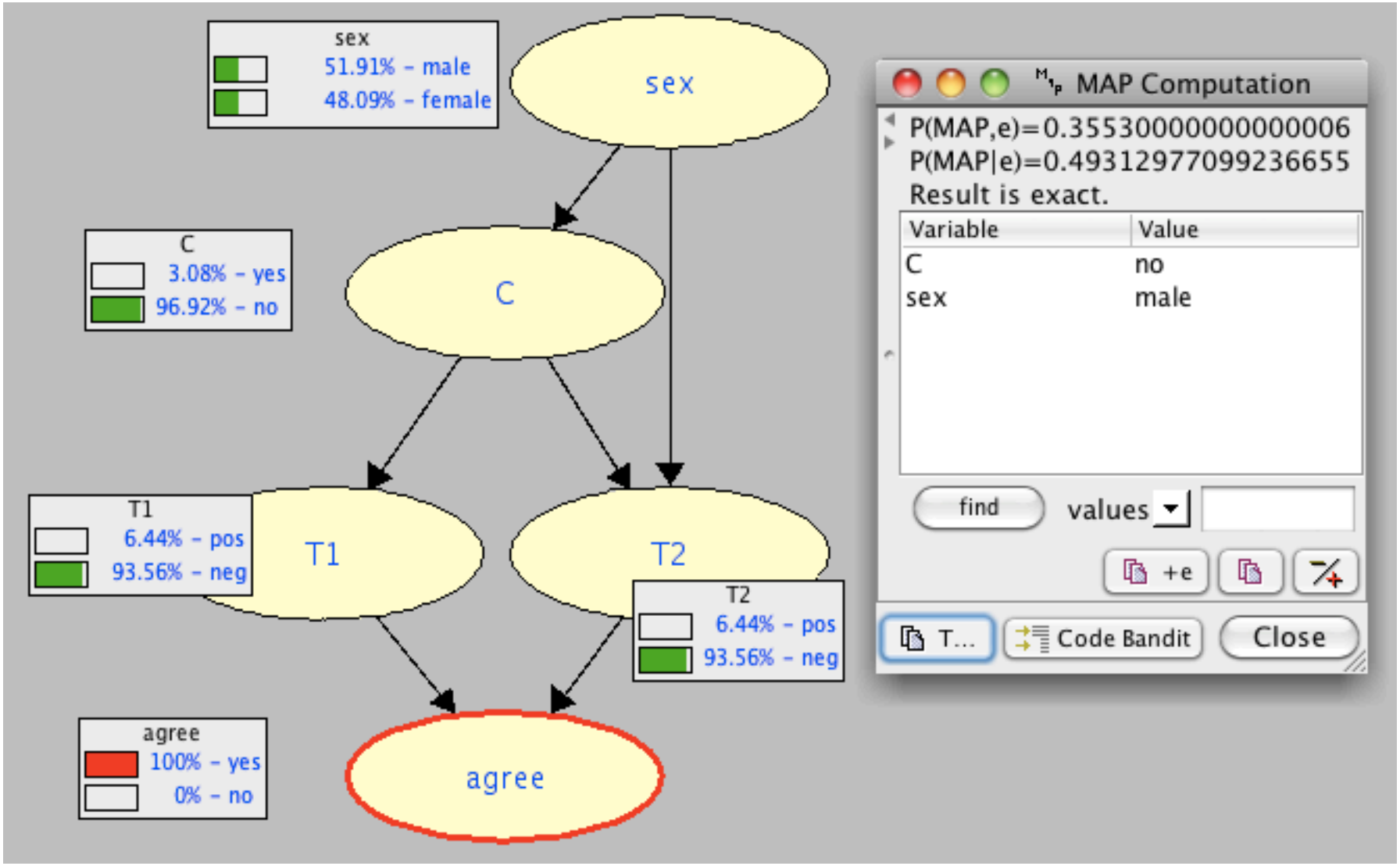

sex
C
T1
T2
agree


sex
51.91% - male
48.09% - female
sex
C
3.08% - yes
96.92% - no
C
T1
6.44% - pos
93.56% - neg
T1
T2
T2
6.44% - pos
93.56% - neg
agree
100% - yes
0% - no
agree

Most Probable Explanation (MPE)



Maximum a Posteriori (MAP)



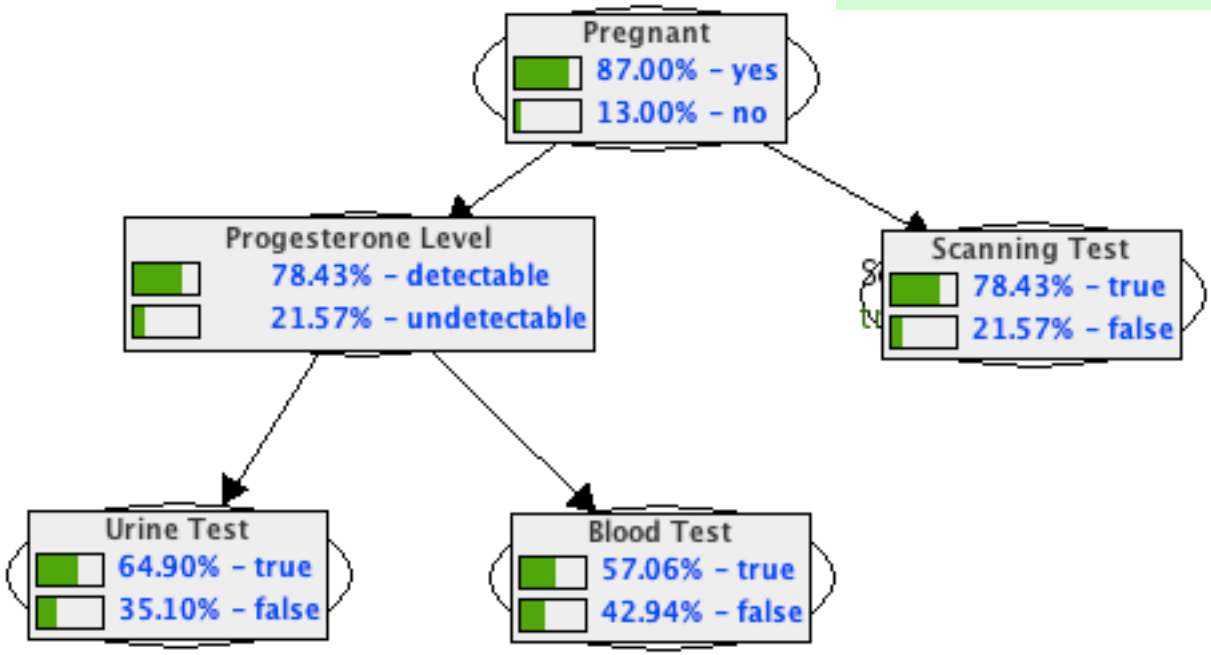
Query Types

- Prior & Posterior Marginals
  (PP-complete)
- MPE: Most probable explanations
  (NP-complete)
- MAP: Maximum a Posteriori Hypothesis
  (NP^{PP}-complete)

- SDP: Same-Decision Probability
  (PP^{PP}-complete)

Same-Decision Probability

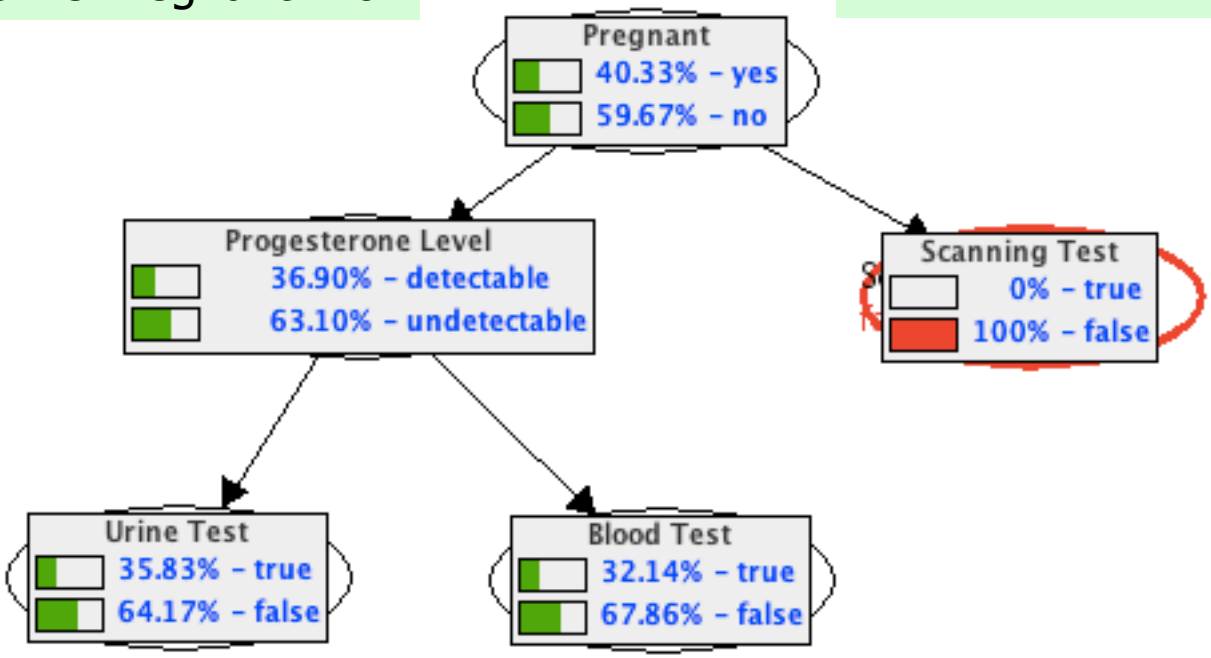
Threshold for Pregnancy is 90%



Same-Decision Probability

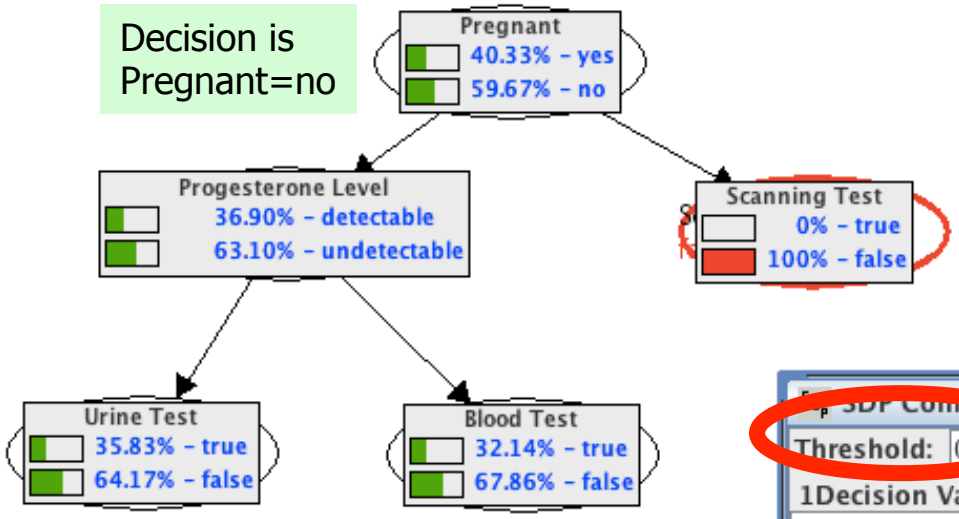
Decision is Pregnant=no

Threshold for Pregnancy is 90%

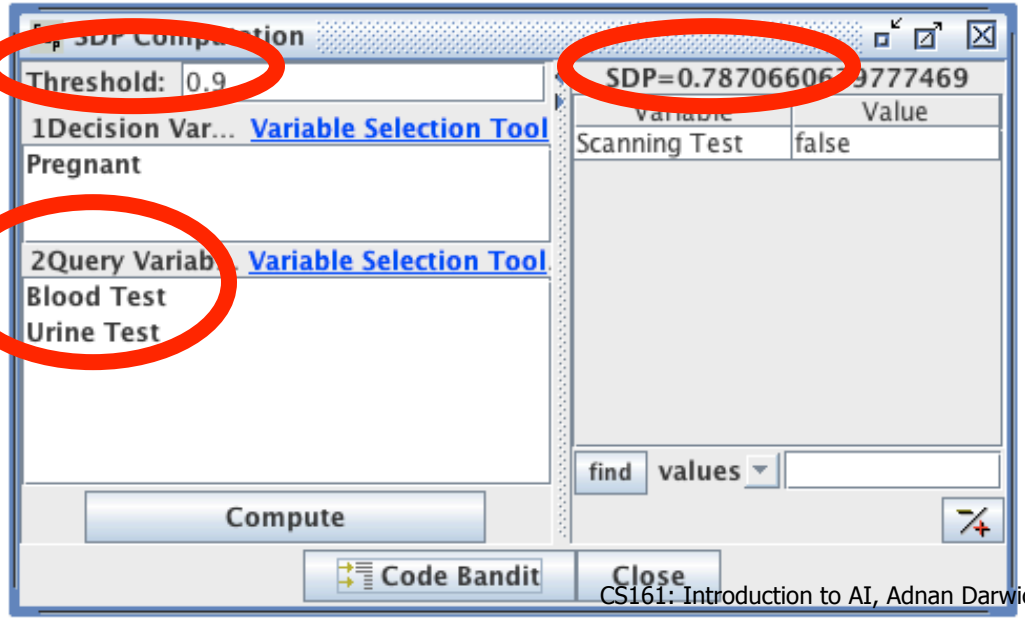


Same-Decision Probability

Decision is Pregnant=no



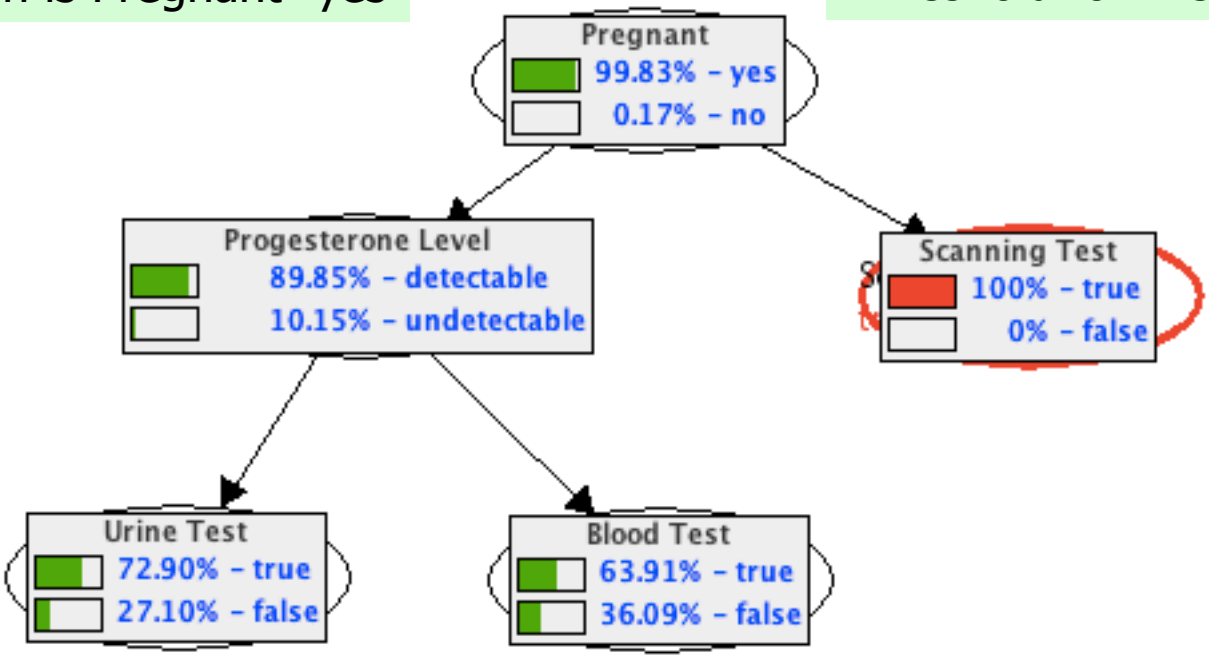
78.7% chance you will still make the same decision after collecting the blood and urine tests.



Same-Decision Probability

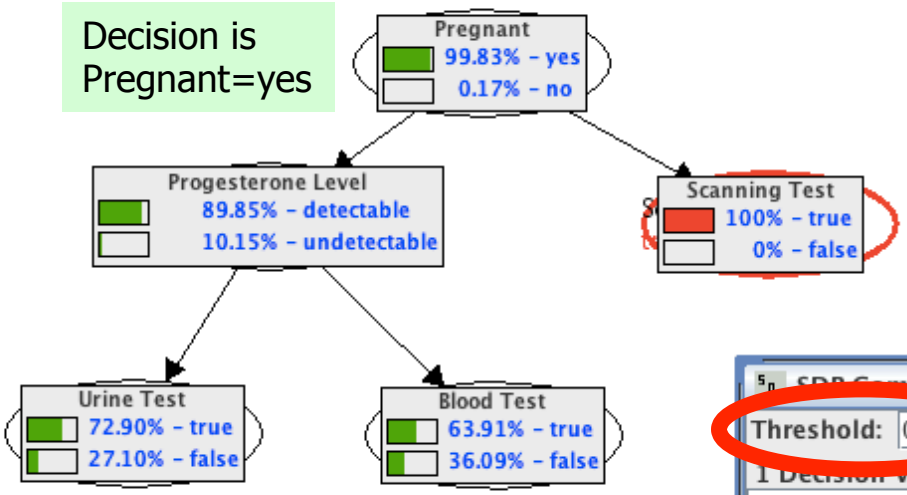
Decision is Pregnant=yes

Threshold for Pregnancy is 90%

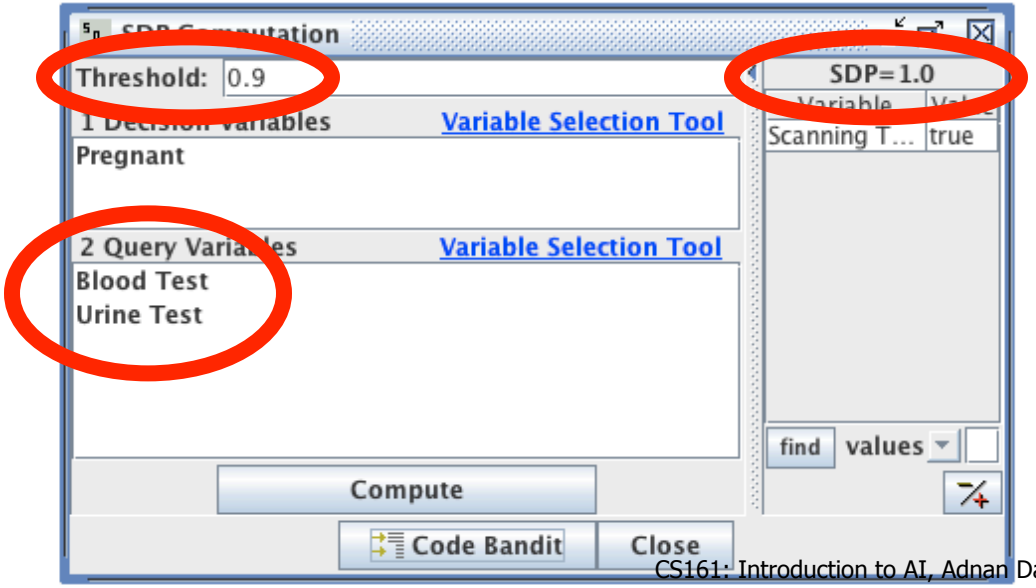


Same-Decision Probability

Decision is Pregnant=yes



100% chance you will still make the same decision after collecting the blood and urine tests.



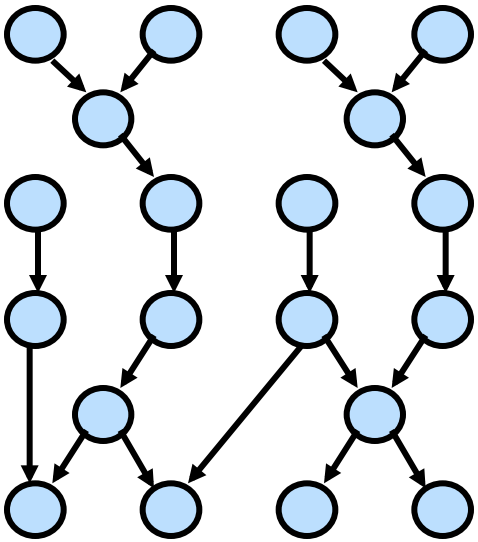
Same-Decision Probability

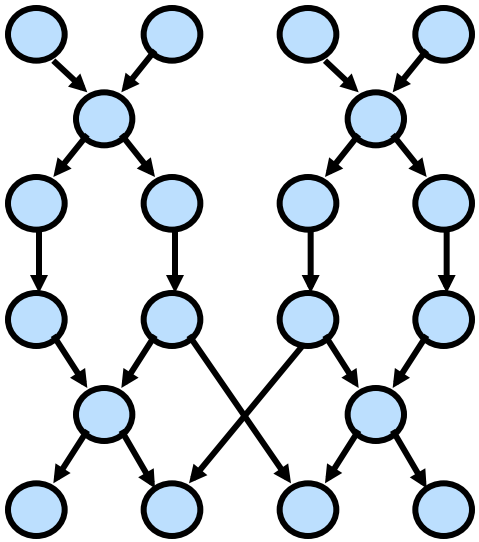
probability that we would have made the same decision had we known some additional information.

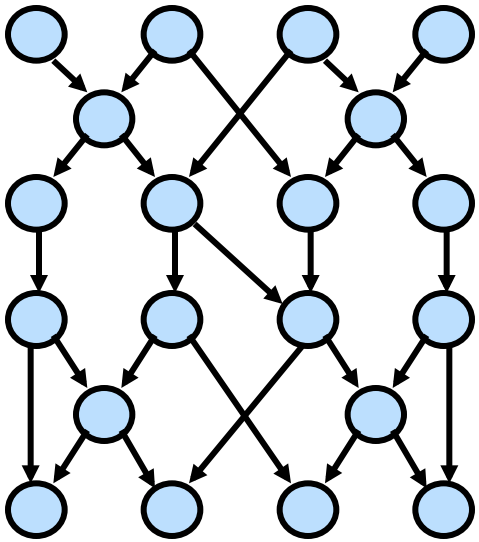
Some Applications

- Evidence: symptoms
  Query: **what disease?**
- Evidence: phenotype, genotype
  Query: **prone to disease?**
- Evidence: words in a document
  Query: **what topics?**
- Evidence: pixels in an image
  Query: **how far are objects from camera?**
- Evidence: credit card transaction
  Query: **is it the owner?**
- Evidence: Speech
  Query: **what words were uttered?**

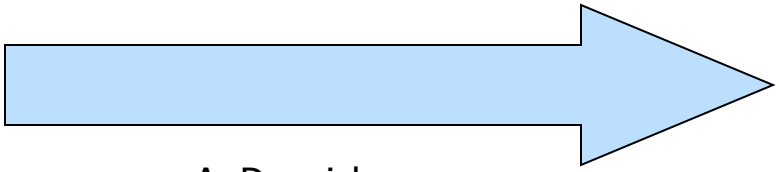
Model Structure: Treewidth w







$$O(n \exp(w))$$



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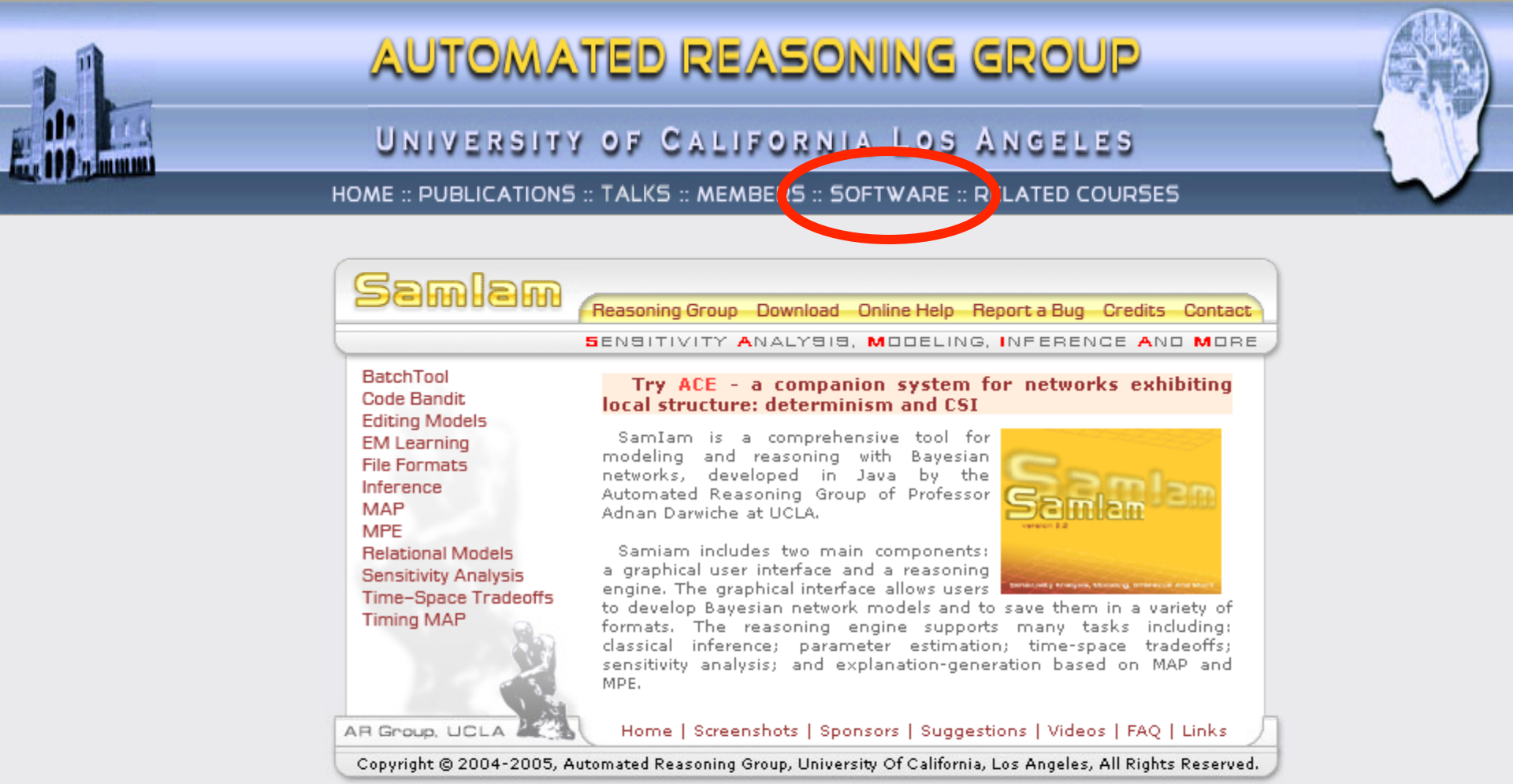
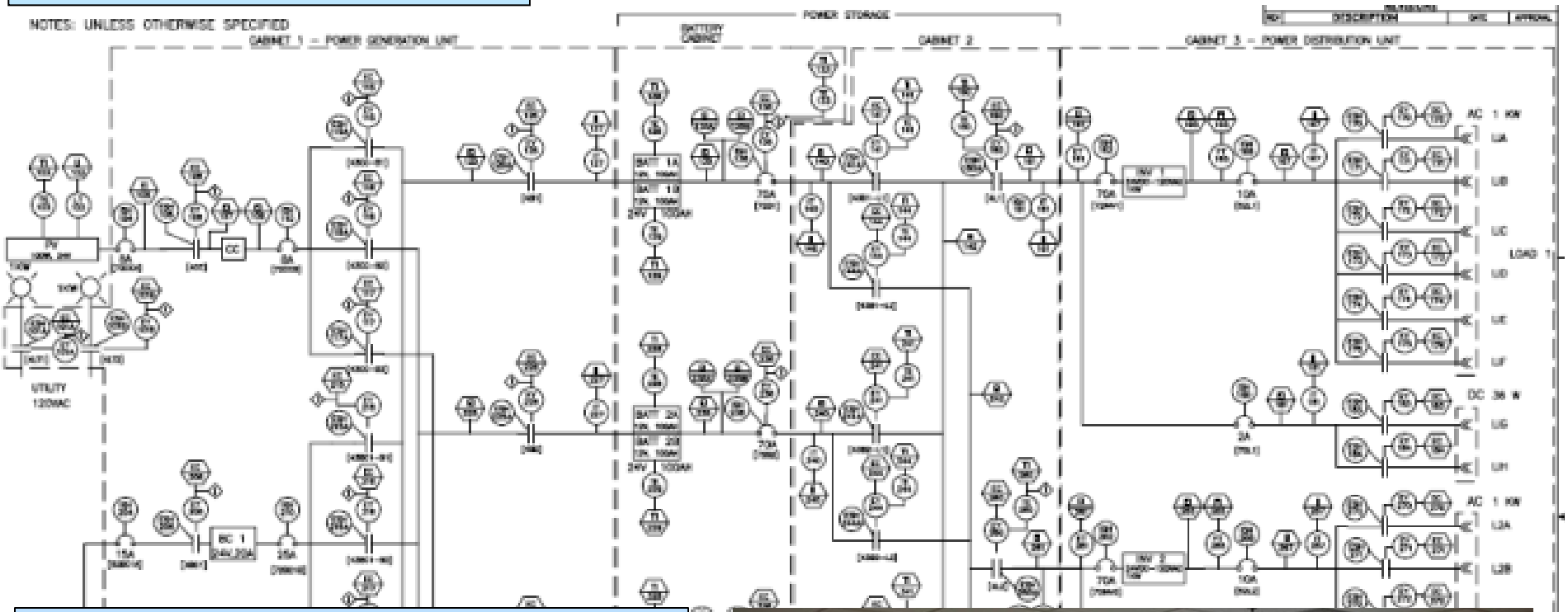


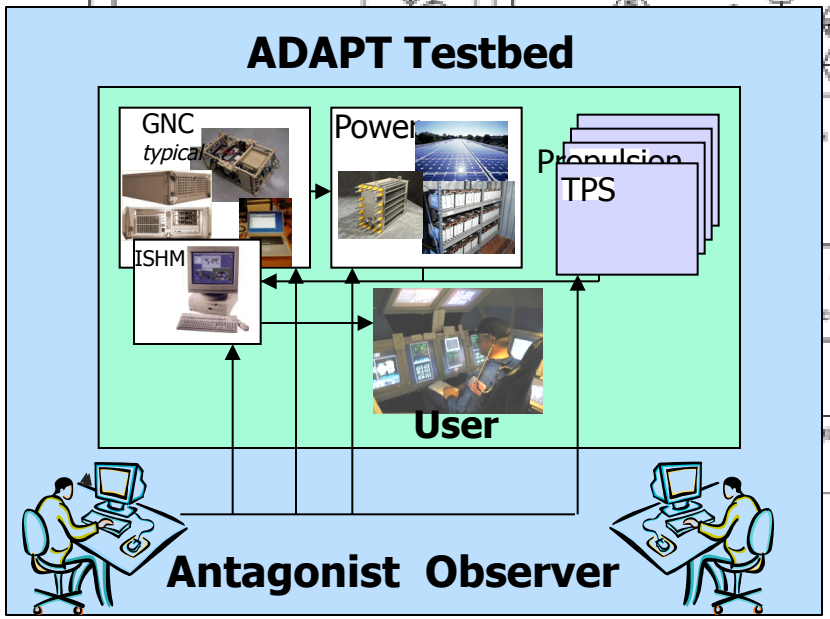
http://reasoning.cs.ucla.edu/samiam/

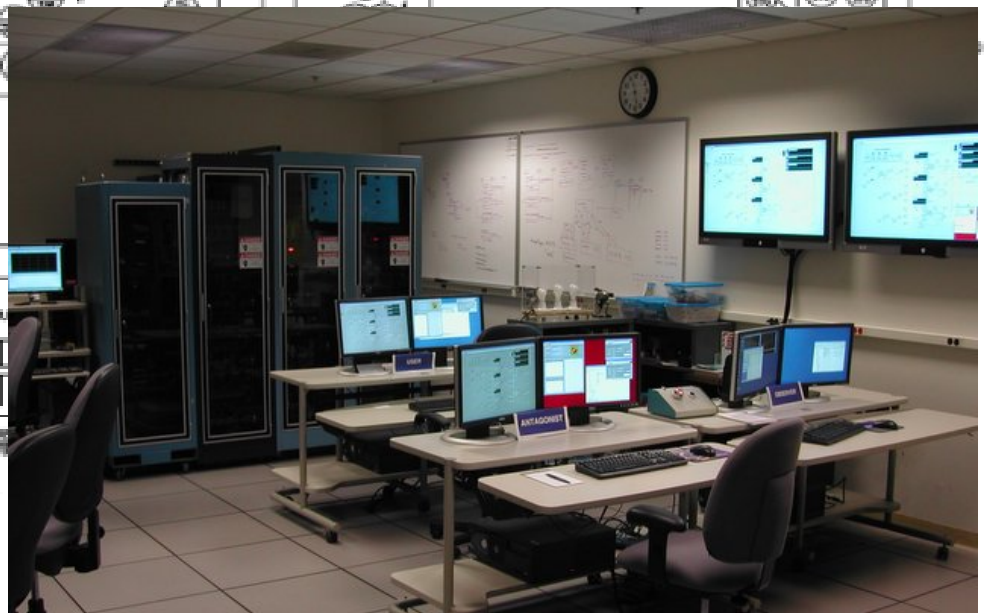
Constructing Bayesian Networks

- Subjective beliefs
- Learning from data
- Synthesis from other type of knowledge

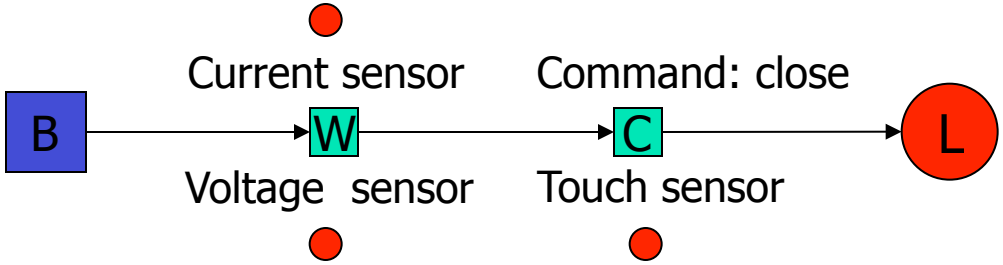
NASA Ames, Mountain View

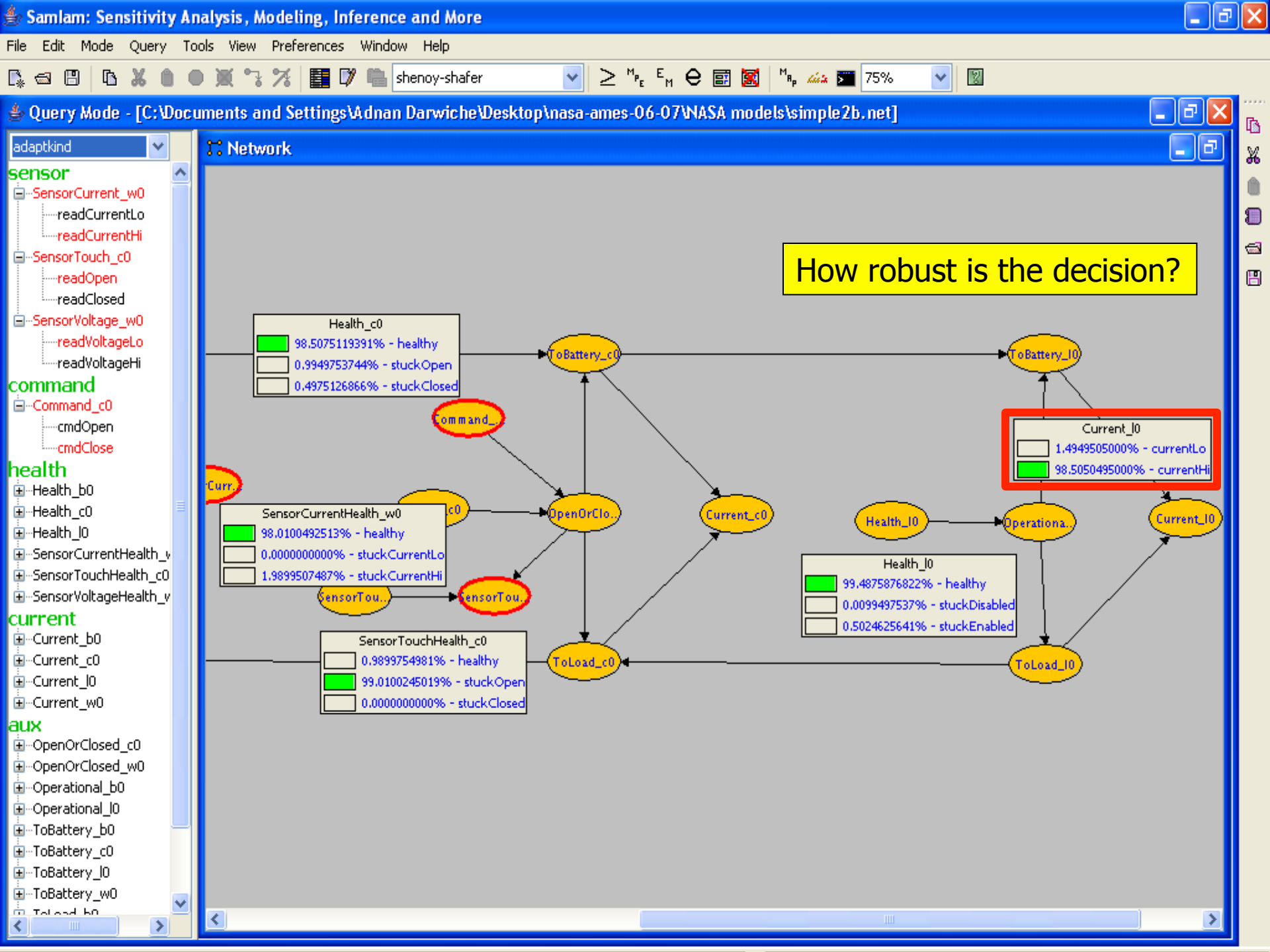






Monitoring and Diagnosis




Samlam: Sensitivity Analysis, Modeling, Inference and More
File Edit Mode Query Tools View Preferences Window Help
shenoy-shafer
75%
Query Mode - [C:\Documents and Settings\Adnan Darwiche\Desktop\nasa-ames-06-07\NASA models\simple2b.net]
adaptkind
sensor
SensorCurrent_w0
readCurrentLo
readCurrentHi
SensorTouch_c0
readOpen
readClosed
SensorVoltage_w0
readVoltageLo
readVoltageHi
command
Command_c0
cmdOpen
cmdClose
health
Health_b0
Health_c0
Health_l0
SensorCurrentHealth_v
SensorTouchHealth_c0
SensorVoltageHealth_v
current
Current_b0
Current_c0
Current_l0
Current_w0
aux
OpenOrClosed_c0
OpenOrClosed_w0
Operational_b0
Operational_l0
ToBattery_b0
ToBattery_c0
ToBattery_l0
ToBattery_w0
Network
How robust is the decision?
Health_c0
98.50751193910% - healthy
0.99497537440% - stuckOpen
0.49751268660% - stuckClosed
ToBattery_c0
ToBattery_l0
Command_..
Current_l0
1.49495050000% - currentLo
98.50504950000% - currentHi
Curr..
SensorCurrentHealth_w0
98.01004925130% - healthy
0.00000000000% - stuckCurrentLo
1.98995074870% - stuckCurrentHi
OpenOrClo..
Current_c0
Health_l0
Operationa..
Current_l0
SensorTou..
SensorTou..
Health_l0
99.48758768220% - healthy
0.00994975370% - stuckDisabled
0.50246256410% - stuckEnabled
SensorTouchHealth_c0
0.98997549810% - healthy
99.01002450190% - stuckOpen
0.00000000000% - stuckClosed
ToLoad_c0
ToLoad_l0

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+ Intelligent Systems Division
+ Discovery and Systems Health
+ Diagnostics and Prognostics

Results in DX Competition

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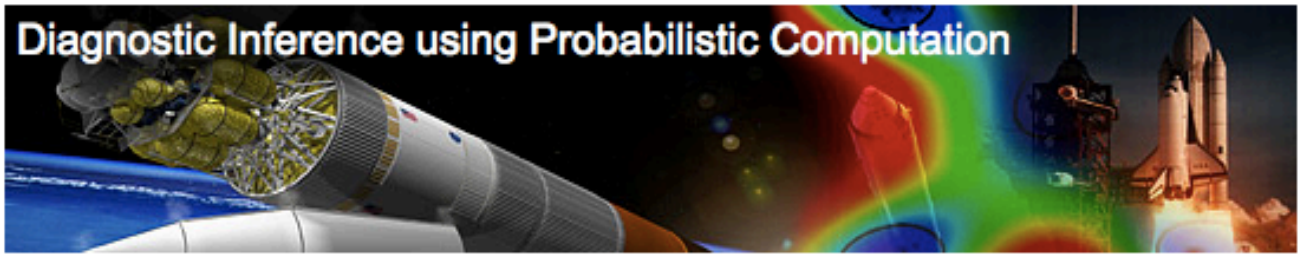
+ Probablistic Approach
+ Probablistic Case Study
+ Initial Results
+ Results in DX Competition
+ References
+ Research Team
+ Collaborators
+ Contact



Results in DX Competition

We have participated in a diagnostic challenge that was organized as part of the 20th International Workshop on Principles of Diagnosis (DX-09); see http://www.isy.liu.se/dx09/ for information about the workshop. The challenge was organized in two tracks, an Industrial Track and a Synthetic Track, and we participated in the Industrial Track featuring the ADAPT electrical power system (EPS) testbed.

Two categories of scenarios were featured in the Industrial Track, namely Tier 1 scenarios (a subset of ADAPT) and Tier 2 scenarios (complete ADAPT). Tier 1 scenarios were nominal or contained one fault. Tier 2 scenarios were nominal or contained single, double, or triple faults.

Faults inserted into ADAPT had the following characteristics:

- Faults were injected simultaneously or sequentially
- Fault types were parametric (change in continuous parameter value) or discrete (change in system mode)
- Faults were abrupt (immediate onset) and permanent
- Faults were to components as well as sensors

Using techniques discussed here, our ProADAPT team obtained the highest scores in both Tier 1 (among 9 international competitors) and Tier 2 (among 6 international competitors) of the Industrial Track of the DX'09 Diagnostic Challenge Competition. One key component of our ProDiagnose algorithm was the use of a Bayesian network model of ADAPT, which was compiled into an arithmetic circuit, which was then used for on-line diagnosis. For further information on the compilation to arithmetic circuits, please see http://reasoning.cs.ucla.edu/. For a high-level discussion of our approach, please see: http://ti.arc.nasa.gov/project/pca/.

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