Using a Perfect Argument in an Imperfect World

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Overview

The role of proof in an assurance case

• Use *eliminative argumentation*
  – Doubts about validity of claims
  – Doubts about validity of evidence
  – Doubts about validity of inferences

• As doubts are eliminated, confidence increases
  – Schema for use of proof
  – Trivial example
  – More realistic example
Schema for Use of Proof in a Case

C1.1  
System S has property P

Cx1.1a  
Specification of "has" in terms of permitted variance in P and confidence that behavior lies within that confidence interval

R2.1  
Unless there is a counterexample

IR2.2  
If no counterexample exists, then System S has property P

Ev3.1  
Proof using model M (of system S) showing Q

Cx3.1a  
Q restates P in terms of model M

IR3.2  
(Inference to reality) If Q holds in model M, then no counterexample exists (for system S)

UM4.1  
But the proof has a bug

UC4.2  
Unless the model is not credible because ...

UC4.3  
Unless P and Q are not equivalent

UC5.1  
The model structure or assumed environment is inconsistent with system S

UC5.2  
Model parameters are inconsistent with system S

UC5.3  
Trivial properties of the model cannot be proven
Triangle Example

B = 4
A = 3
C
Triangle Example

C1.1
In physical triangle ABC (system S), C = 5

Cx1.1a
C = 5 means C lies within 0.02 of 5 with 99% confidence

R2.1
Unless when A = 3 and B = 4, C is not to equal to 5

IR2.2
If there is no possibility that C /= 5, then C = 5

Ev3.1
Proof using model M showing C' = sqrt(A'A' + B'B'), and so C' must equal 5

IR3.2
(Inference to reality) If C' = 5 in the model then C must equal 5 in system S

UC4.1
Unless the model is not credible because ...

UC4.2
Unless C'=5 is not equivalent to saying C=5

UC5.1
The physical triangle does not lie in a plane

UC5.2
The actual values of A, B, and angle AB are too different from those in model M

UC5.3
Angles A'C' and B'C' do not sum to 90 degrees
Calculating Confidence

A = 3 ± 0.02 (with 99% confidence)
B = 4 ± 0.02 (with 99% confidence)
\( \alpha = 90^\circ \pm 1.0^\circ \) (with 99% confidence)
C = sqrt \((A^2 + B^2 - 2AB \cos(\alpha))\)
Calculating Confidence

C = 5±0.05 (99% confidence)

C = 5±0.02 (66% confidence)
Calculating Confidence

Were fortunate to have a way of calculating how inaccuracies in the model would affect confidence in the conclusion

• Probabilistic variations in the model
• Affect confidence gained from the proof
• The analysis suggests where to strengthen the case
C1.1  The engine (system S) cannot be started by an unauthenticated user (property P)

R2.1  Unless the authentication protocol has a defect that allows an unauthenticated user to start the engine

Ev3.1  A proof using a state machine model of the authentication protocol showing that the "start engine" node cannot be reached by unauthenticated users

IR2.2  If the authentication protocol has no defects, then an unauthenticated user cannot start the engine

Cx1.1a  pfd < 0.001 with 99% confidence,

UM4.1  But there is a bug in the proof
C1.1
The engine (system S) cannot be started by an unauthenticated user (property P)

Cx1.1a
pf < 0.001 with 99% confidence,

R2.1
Unless the authentication protocol has a defect that allows an unauthenticated user to start the engine

Ev3.1
A proof using a state machine model of the authentication protocol showing that the "start engine" node cannot be reached by unauthenticated users

IR2.2
If the authentication protocol has no defects, then an unauthenticated user cannot start the engine

IR3.2
If the "start engine" node in the state machine model cannot be reached by an unauthenticated user, then the actual authentication protocol doesn't permit unauthenticated users to start the engine

UM4.1
But there is a bug in the proof

UC4.2
Unless the model is not credible because ...

UC4.3
Unless the theorem proven in the model does not correctly express the authentication property
Model Credibility Evidence

UC4.2
Unless the model is not credible because...

UC5.1
The states, transitions, and environmental conditions of the model are inconsistent with the authentication protocol design

UC5.2
State transition conditions, frequencies, etc. are inconsistent with the actual operation of the engine

UC5.3
Trivial properties of model M cannot be proven

C6.1
The current model is a revision of earlier models in which property P could not be proven

C6.2
The model was derived by a tool using the actual code

C6.3
Every node can be reached

C6.4
Internal consistency checks all pass
Summary

Used Eliminative Argumentation to explore role of proofs in an AC

Considered how to use the proof as a guide for estimating the extent to which one can have confidence in the application of the proof result to the real world
  • Modeling inaccuracies
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