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On The Interpretation and Evaluation of Assurance Case Arguments

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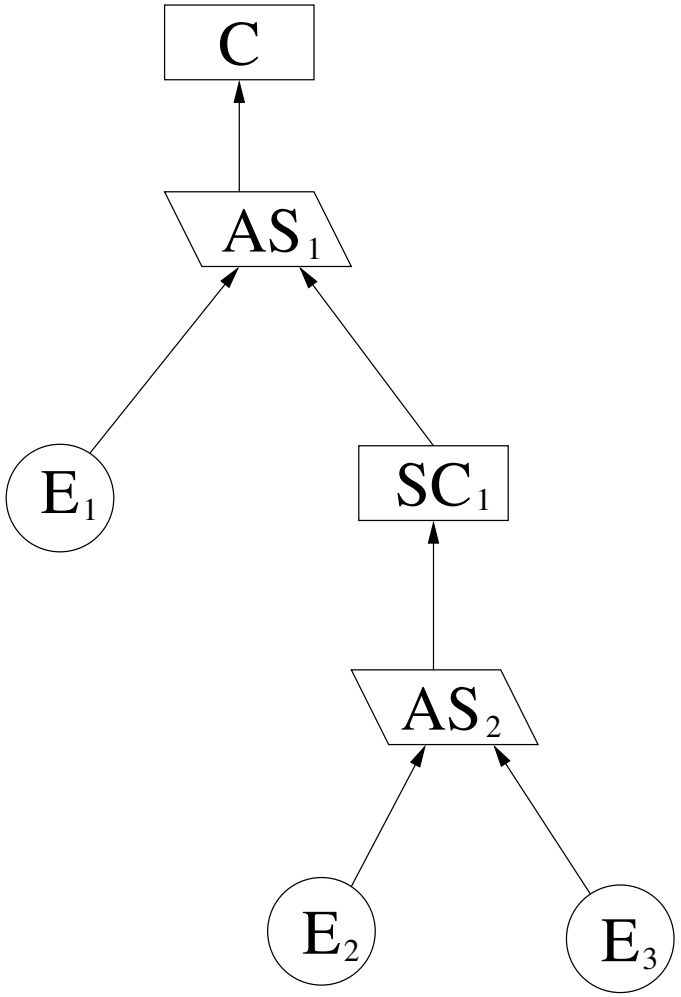
Assurance Case Arguments

- The idea is that we "make the case" to justify deployment of some system by
  - Stating the claim that it must satisfy
    - ⋆ Often safety-related
  - Developing evidence about its assumptions, design, performance etc.
  - Constructing as structured argument that justifies the claim, based on the evidence

- How should we interpret these arguments?
  - i.e., what are their semantics?

- And how do we tell if an argument is (sufficently) sound?

Structured Argument



C: Claim

AS: Argument Step

SC: Subclaim

E: Evidence

A hierarchical arrangement of argument steps, each of which justifies a claim or subclaim on the basis of further subclaims or evidence

Inductive and Deductive Arguments

- The world is an uncertain place (random faults and events)
- Our knowledge of the world is incomplete, may be flawed
  - Our reasoning may be flawed also
- So an assurance case cannot expect to prove its claim
- Hence, the overall argument is inductive
  - Evidence & subclaims strongly suggest truth of top claim
- Rather than deductive
  - Evidence & subclaims imply or entail the top claim
- But if the overall argument is inductive
  - Does that mean all its steps may be inductive too?
- That is, we necessarily have doubts
  - But where may they be located?
  - And how are they controlled?

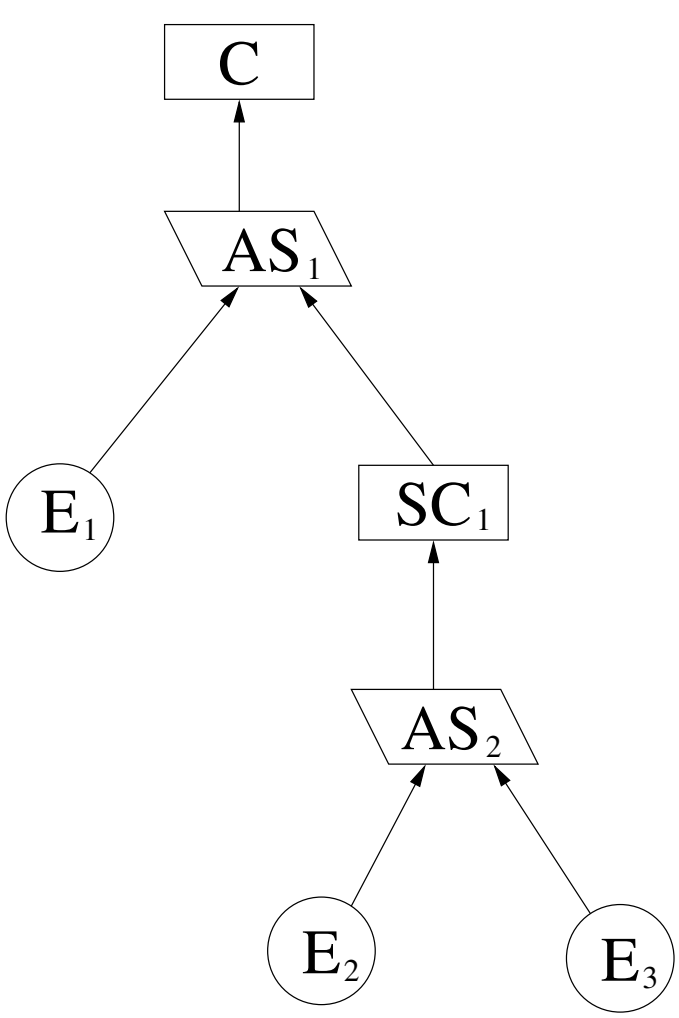
Traditionally. . .

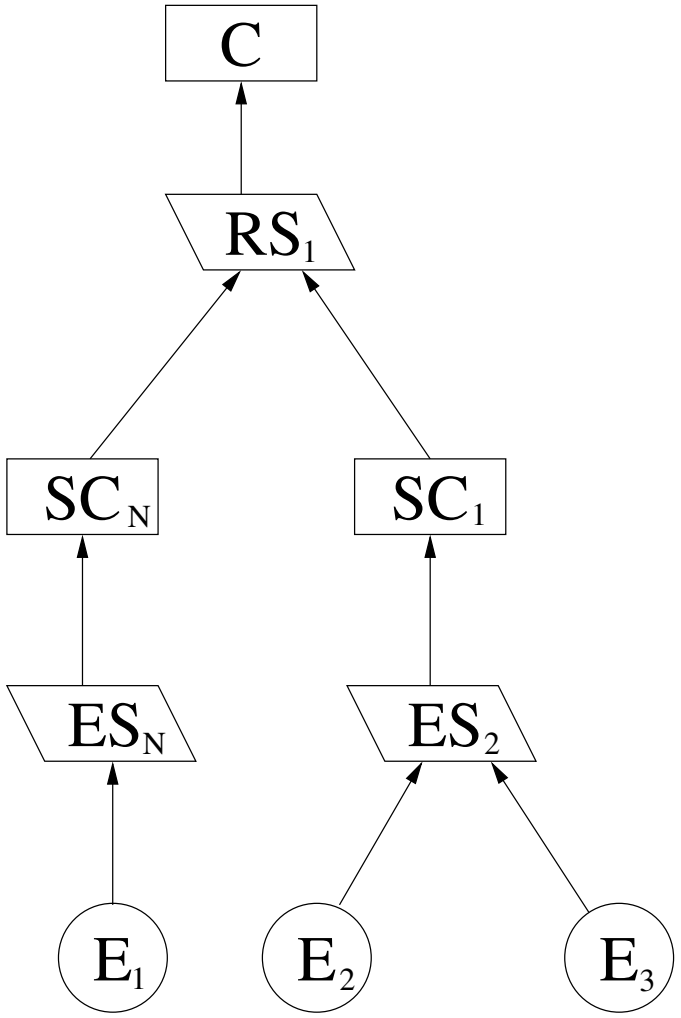
- Traditionally, every argument step can be inductive
- Considered unrealistic to be completely certain
  - cf. ceteris paribus hedges in science
- Then there's a tricky notion of confidence items
  - Evidence or subclaims that do not directly contribute to the argument
  - i.e., their falsity would not invalidate the argument
  - But their truth increase our confidence in it
- Eh?

Argument Steps and Layered Arguments

- We decompose top-level claim into conjunction of subclaims
- And iterate
- Until we get down to subclaims supported by evidence
- Provide a narrative justification for each step
- Can normalize so there are just two kinds of argument steps
  - Reasoning steps: subclaim supported by further subclaims
  - Evidential steps: subclaim supported by evidence
    - ⋆ Can allow claims as assumptions on evidential steps
- Call this a simple form argument

Normalizing an Argument to Simple Form





RS: reasoning step; **ES**: evidential step

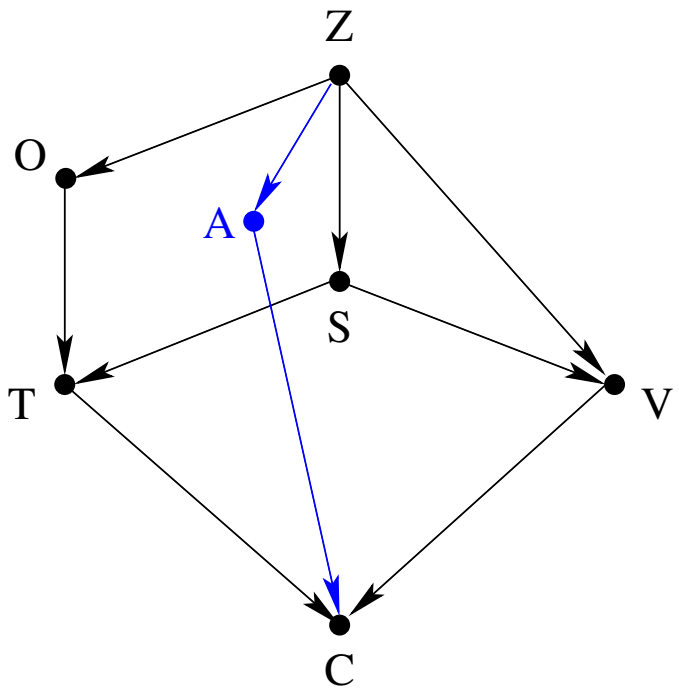
Why Normalize In This Way?

- Because the two kinds of argument step should be interpreted differently
- Evidential steps
  - These are about epistemology: knowledge of the world
  - Bridge from the real world to the world of our concepts
  - Have to be considered inductive
  - Multiple items of evidence are "weighed" not conjoined
  - Confidence items can be part of the weighing
- Reasoning Steps
  - These are about logic/reasoning
  - Conjunction of subclaims leads us to conclude the claim
    - ⋆ Deductively: subclaims imply claim
    - ⋆ inductively: subclaims suggest claim
  - Very hard to see what confidence claims do

Weighing Evidential Steps

- We measure and observe what we can
- To infer a subclaim that is not directly observable
- Different observations provide different views
  - Some more significant than others
  - And not all independent
- "Confidence" can be observ'ns that vouch for others
  - Or provide independent backup
- Need to "weigh" all these in some way
- Probabilities provide a convenient metric
  - And Bayesian methods and BBNs provide tools
  - There's also Bayesian Confirmation Theory
- I do not think the exact numbers and methods are important
  - Use BBNs for what-if investigations
  - To help develop insight and sharpen judgement

Weighing Evidential Steps With BBNs



Z: System Specification

O: Test Oracle

S: System's true quality

T: Test results

V: Verification outcome

A: Specification "quality"

C: Conclusion

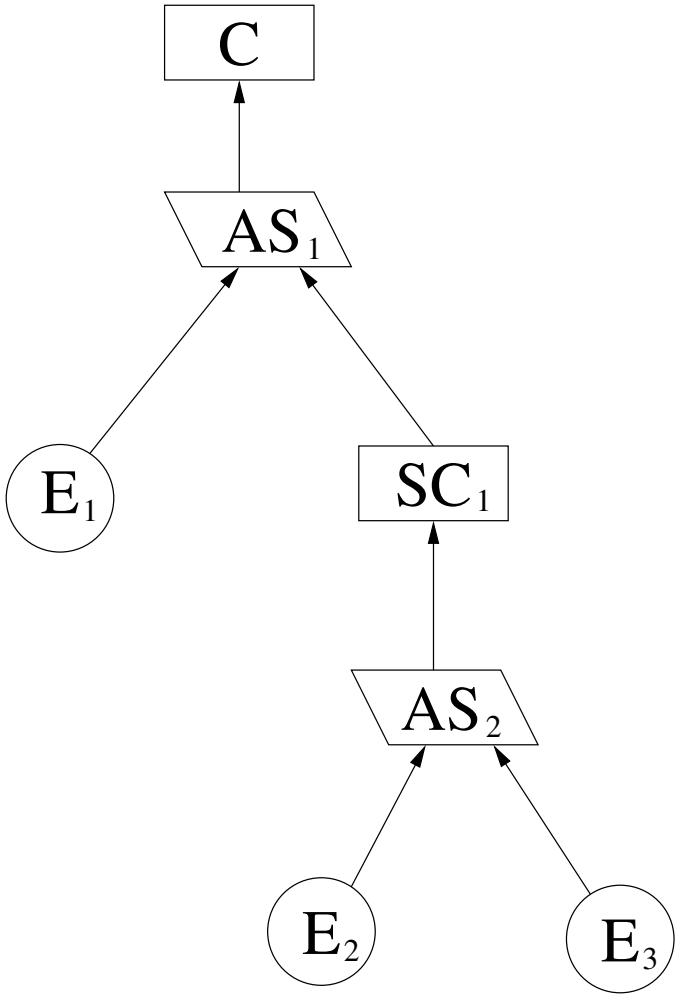
Example joint probability table: successful test outcome

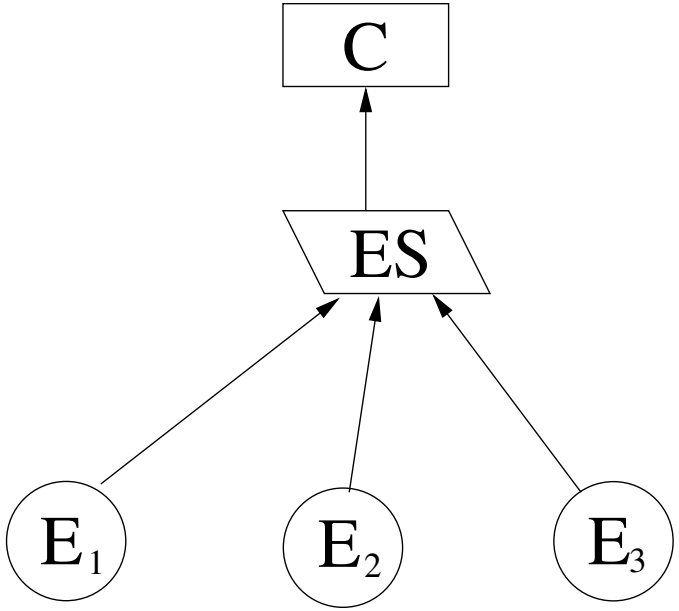
Correct System		Incorrect System	
Correct Oracle	Bad Oracle	Correct Oracle	Bad Oracle
100%	50%	5%	30%

Evaluating Reasoning Steps

- We could replace each subclaim by its supporting evidence
- Thereby flattening the argument
- And then apply BBNs to the whole lot

Collapsing an Argument





Evaluating Reasoning Steps (ctd.)

- There's a reason we don't do this
  - An assurance case is not just a pile of evidence
    - ⋆ That's DO-178C, for example
  - It is an argument
  - With a structure based on our reasoning about the system

- So the reasoning steps should be interpreted in logic
  - As conjunctions that imply or suggest their parent claim

Validating Reasoning Steps with Defeaters

- Validate reasoning steps by trying to think of defeaters
  - Circumstances where subclaims hold but claim does not
  - It's like hazard analysis, but applied to arguments
- Can do this ourselves, or in dialog with reviewers
- Do not challenge the individual subclaims
  - Those are validated (recursively) at lower levels
  - Treat them here as settled facts
- Look for gaps in the conjunction
- And fill them in with additional or modified subclaims
- This will tend to make inductive steps deductive
  - By finding the gaps or "assurance deficits"
  - Subclaims are of our own choosing, so choose well
- My opinion is that all reasoning steps should be deductive
  - Inductive is too low a bar, too fungible, indefinite

Evaluating the Soundness of an Argument

- Arguments should be in simple form
- Reasoning steps should be deductive
  - Evaluate by actively seeking defeaters
  - No role for confidence claims in reasoning steps
    - ⋆ "voluminous, rambling, ad infinitum arguments"
- Evidential steps are evaluated by weighing the evidence
  - Can also be challenged by seeking defeaters
  - Evidence may include confidence items
  - Weighing can be done informally
  - Or formalized and mechanized with BBNs
  - Must cross some threshold so that reasoning steps can regard evidential claims as settled facts
- Overall case is then sound

Graduated Assurance

- Many cert'n regimes recognize different levels of criticality
- Less assurance required for lower levels
- Assume the high level case is sound
  - We deliberately weaken it for lower levels
  - So those cases cannot be sound
  - How to do this responsibly?
- Remove some subclaims?
  - Equivalently, retain but require no evidence
  - Wrecks the model: reasoning steps no longer deductive
- Weaken evidence?
  - Lower the bar for settled facts
  - Seems acceptable, but must do it evenly
- Build a different case?
  - E.g., DO-178C without low level specifications
  - Also seems acceptable

Evaluating the Strength of an Argument

- Although I don't advocate flattening then BBNs
  - As a way to evaluate soundness of an argument
- It could be a way to quantify strength of a sound argument
- More simply
  - Just sum (Adams' Uncertainty Accumulation)
  - Or multiply (independence assumption)

  The probabilities calculated (by BBNs) for evidential steps
- Beware of gaming:
  - Combining subclaims to maximize strength measure
- Could do this on an ordinal scale (low, medium, high, etc.)
- Note that it's a weakest link calculation
- Graduated assurance retains soundness, reduces strength

Conclusion

- Interpretation is a combination of probability and logic
- (Possibly informal) probabilities for evidential steps
- Logic for reasoning steps
- Case is sound **if** evidential steps cross some threshold **and** reasoning steps are deductively valid
- Validate by seeking defeaters
- Graduated Assurance may weaken evidential support
- But must not eliminate subclaims or their evidential support
- Overall strength of a sound case is determined by weakest evidential step
- Can formalize this in probability logic, but I think the real appeal has to be to intuition and consensus. . .
- What do you think?

Links

- Lengthy report: http://www.csl.sri.com/users/rushby/papers/sri-csl-15-1-assurance-cases.pdf

- VeriSure Workshop (part of CAV) on "What is an Assuance Case," 18 July 2015, San Francisco: http://fm.csl.sri.com/verisure