Formal Methods and Software Engineering in Certifying Deep Learning

AISafety2019@IJCAI2019

Xiaowei Huang, University of Liverpool

Outline

Engineering AI Safety

Safety Risk

State-of-the-art

Challenges and Gaps

- AI Safety Foundations
- Specification and Modelling
- Verification and Validation
- Runtime Monitoring and Enforcement
- Process Assurance and Certification
- Human-Machine Interaction
- Safety-related Ethics, Security and Privacy

Engineering AI Safety

Safety Risk

State-of-the-art

Challenges and Gaps

Safety Risk

- Robustness risk
- Generalisation risk
- Understanding risk
- Interaction risk

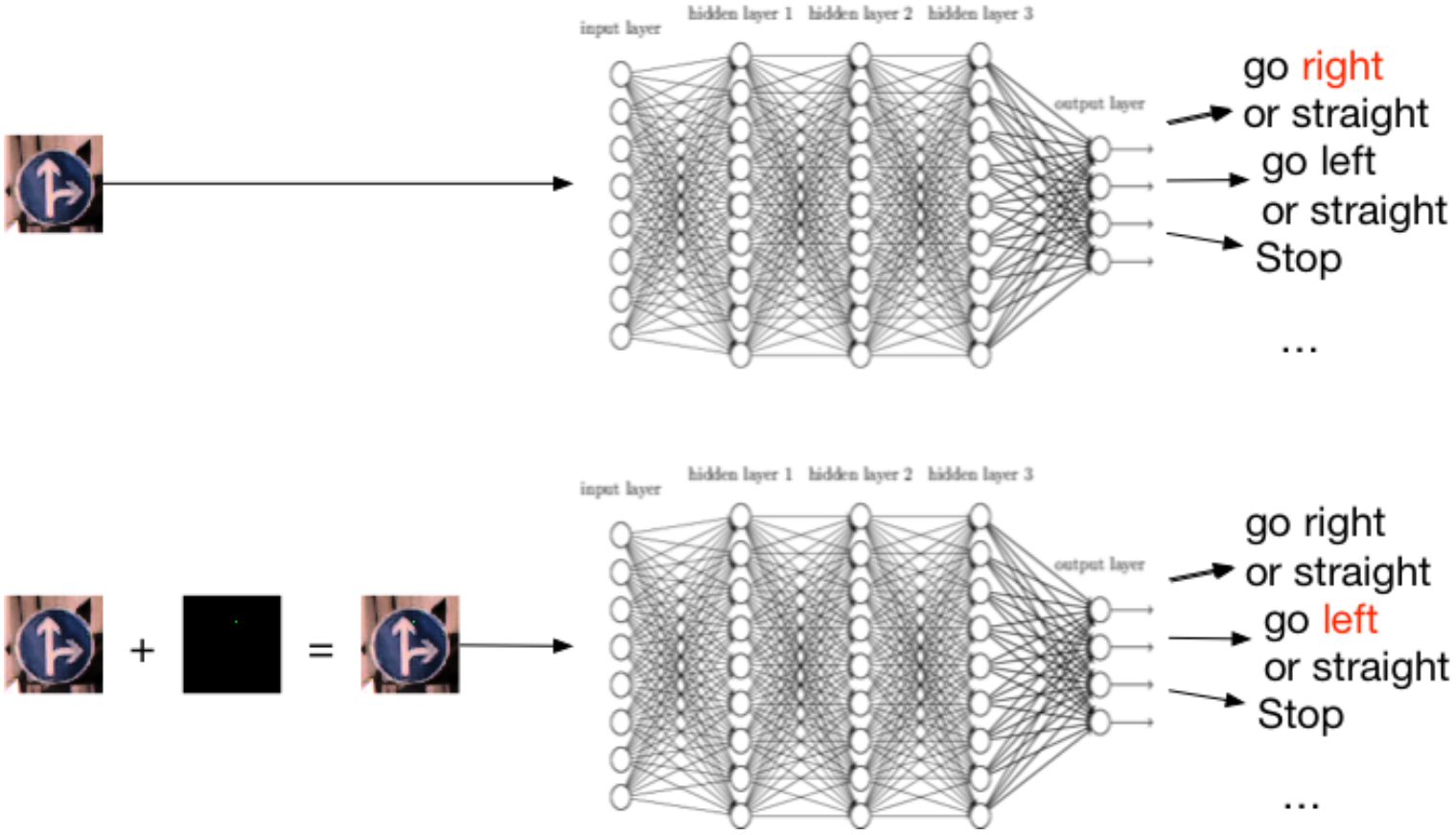
Robustness Risk

robustness

e.g., one pixel change
does not affect decision

- Risk: a small perturbation on the input may lead to a significant difference in terms of the decision making.

Robustness Risk



Generalistion Risk

generalisation

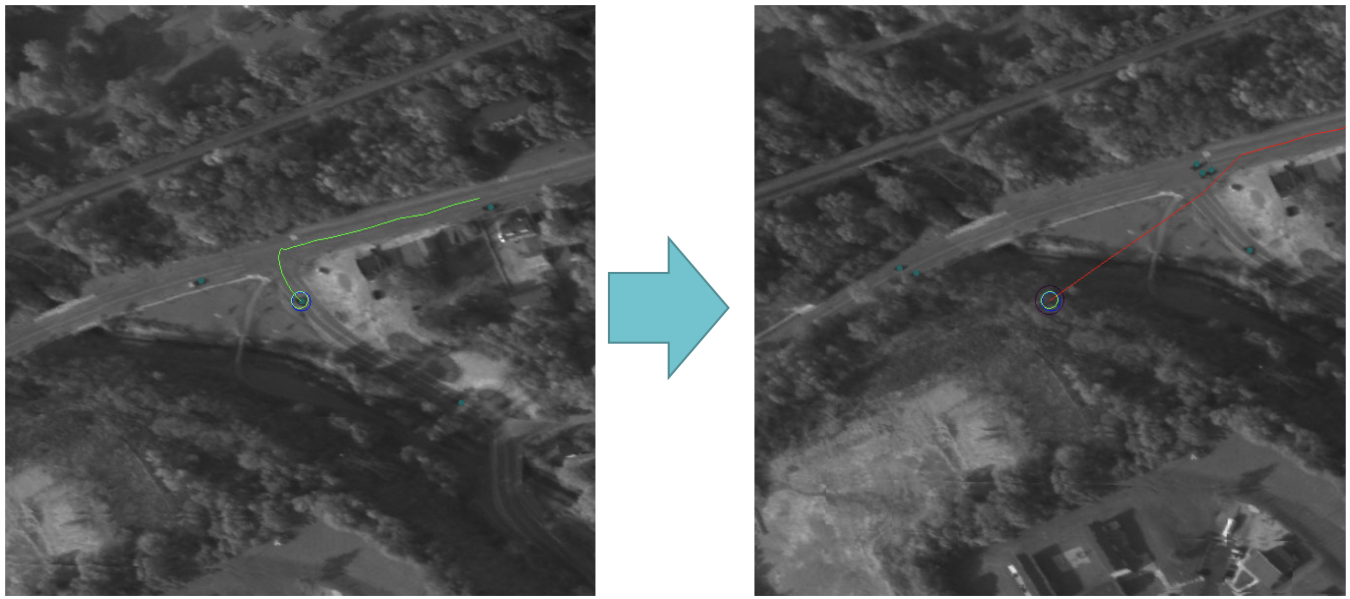
e.g., correctness of decision
preserves across scenarios

- Risk: a change to scenario (environment, unimportant features, etc) leads to unexpected change in decision.

Understanding

- e.g., why does this image represent a traffic sign of “go ahead or turn right”, instead of “go ahead”?
- Risk: a decision is based on incorrect understanding about the input. This can easily lead to wrong decisions.

(Un-)reliability of a vehicle tracking system in wide area motion imagery (WAMI) where there are deep learning components.



Normal tracking

Wrong tracking

- Risk: interaction with other components may introduce risks.

Engineering AI Safety

Safety Risk

State-of-the-art

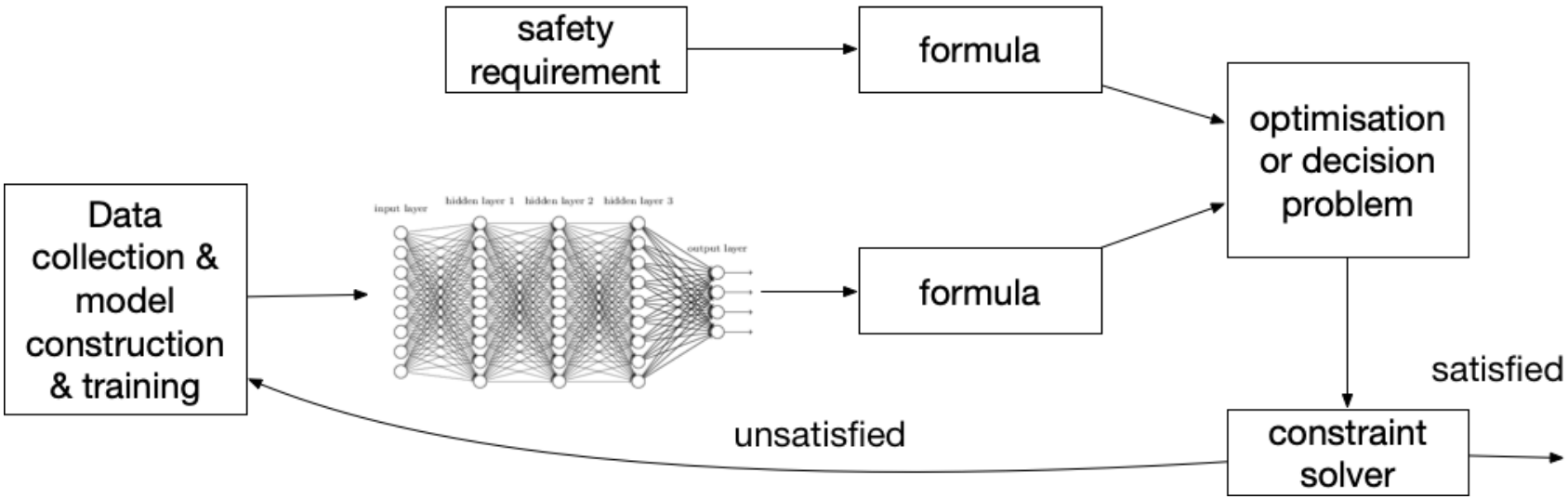
Challenges and Gaps

State-of-the-art

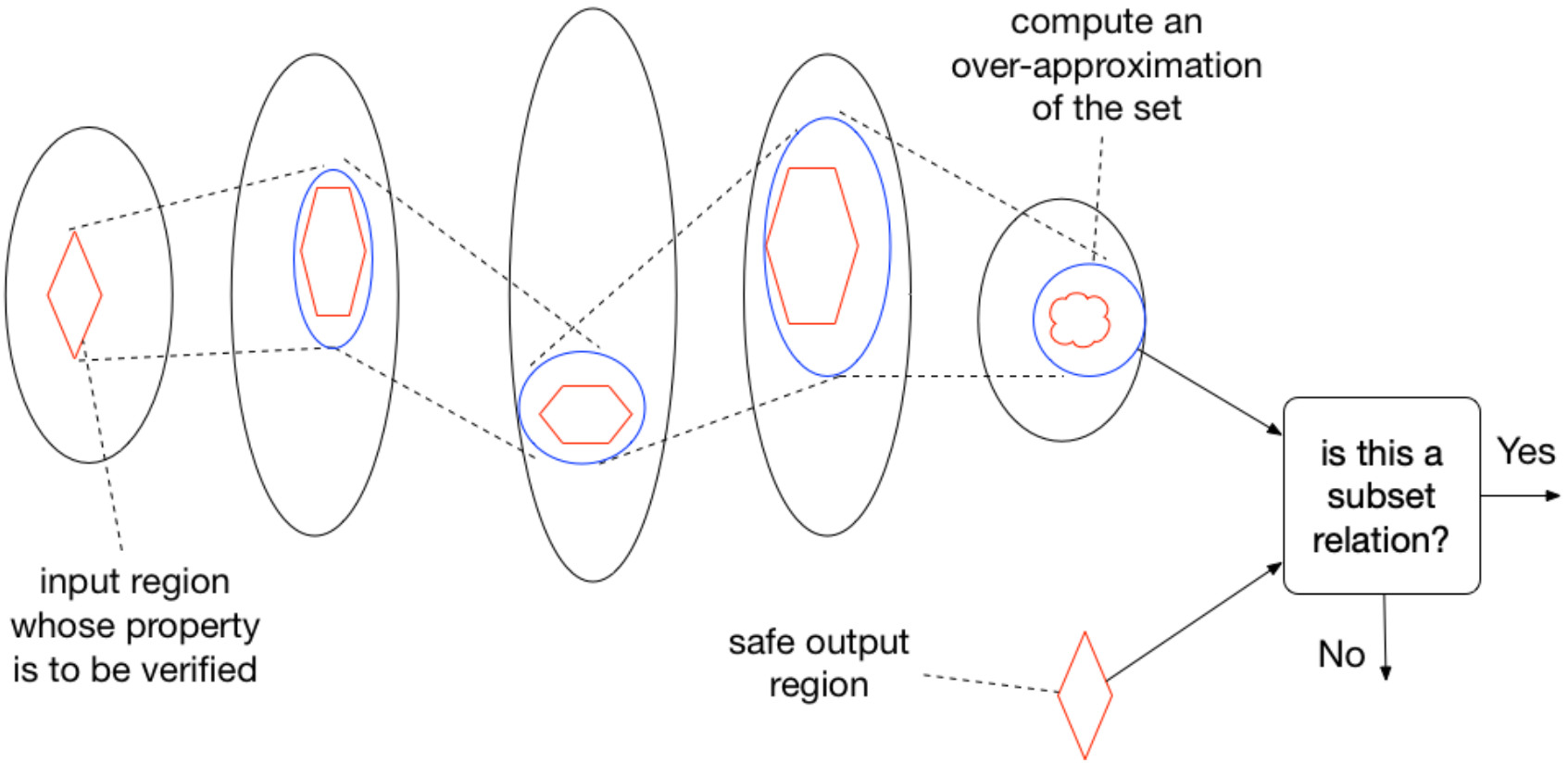
- formal verification
  - constraint solving based methods
  - approximation methods
  - anytime methods
- engineering based methods
  - test coverage metric & test case generation

All for "Verification and Validation" and robustness risk, how about "specification and modelling", "runtime monitoring and enforcement", and "process assurance and certification"?

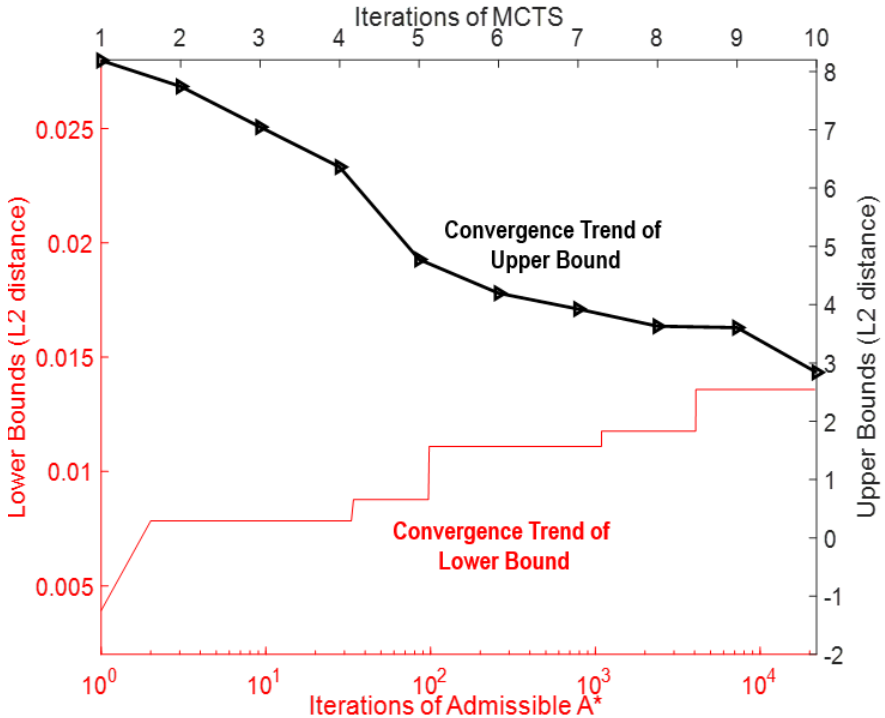
General idea of constraint solving based methods

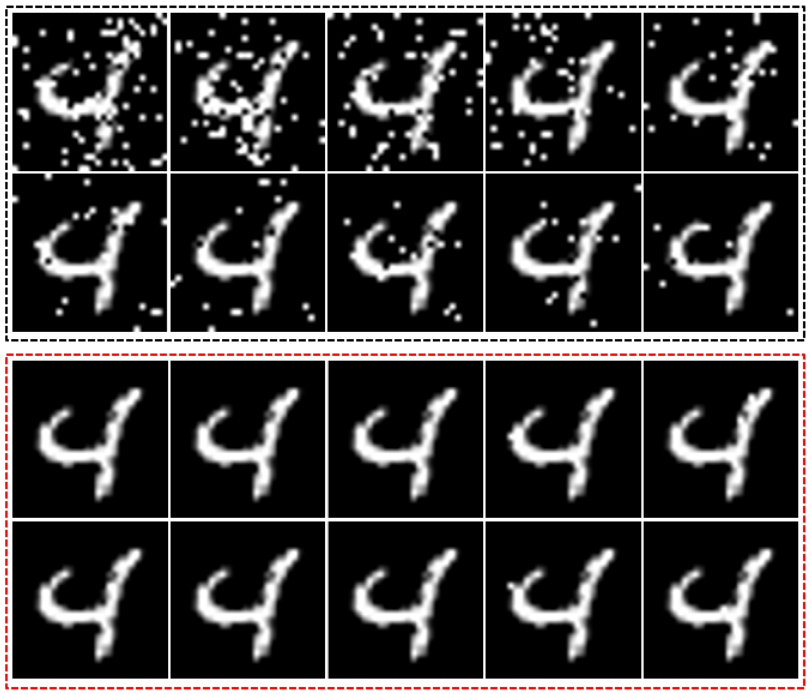


General idea of approximation methods

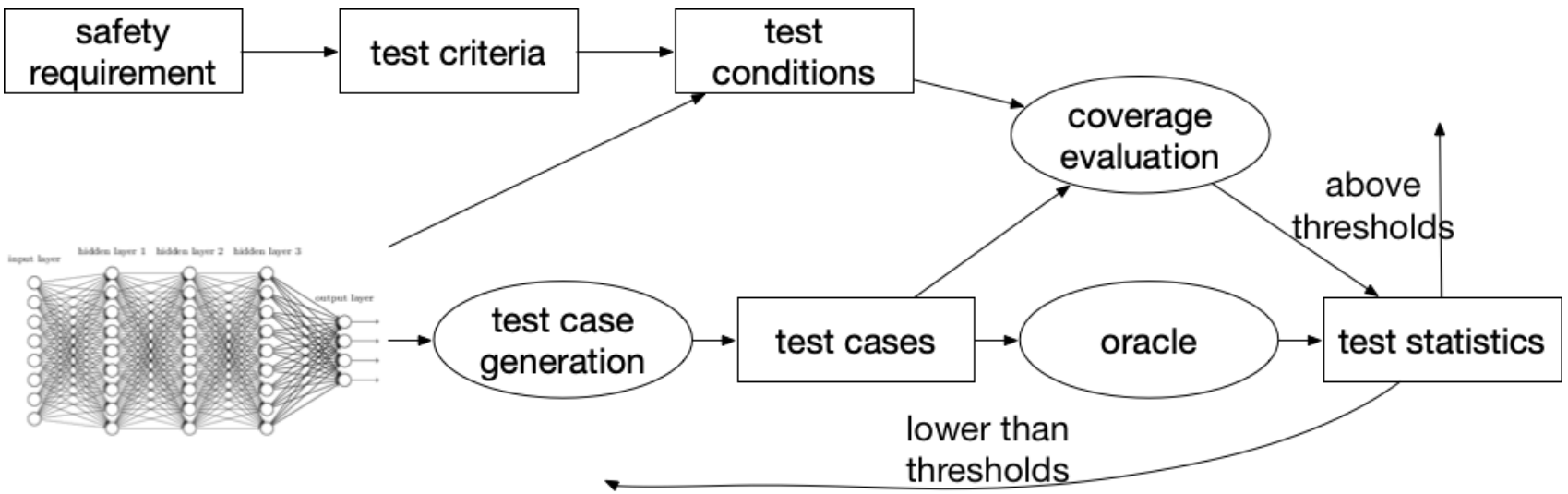


General idea of anytime method





Coverage-based testing methods



Engineering AI Safety

Safety Risk

State-of-the-art

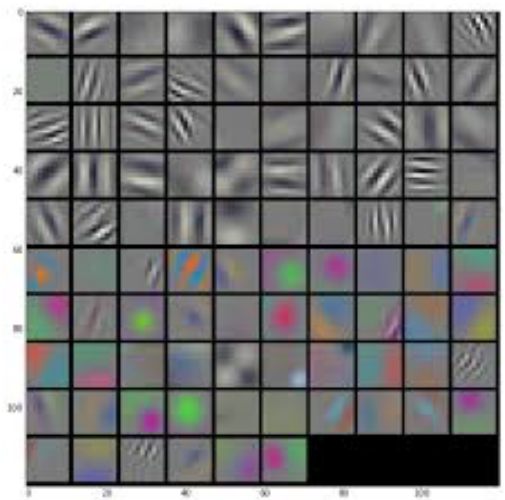
Challenges and Gaps

Challenges and Gaps

- Specification and Modelling
  - what is formal language (as Petri Nets, CASL, UML, etc in traditional software/hardware)?
  - specification = training dataset?

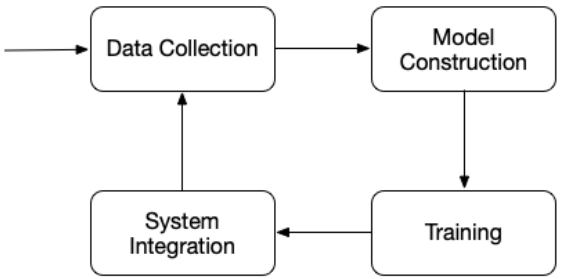
Challenges and Gaps

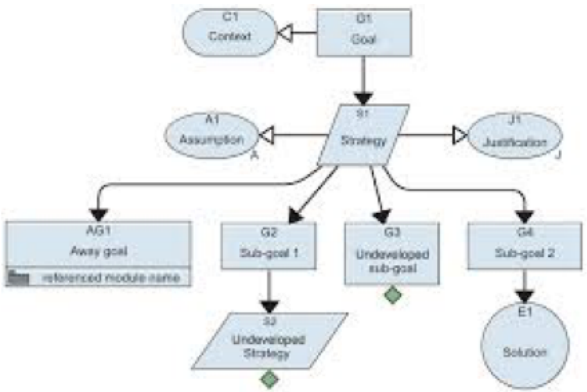
- Verification and Validation
  - improved scalability for robustness verification
    - need a level of abstraction $\Longrightarrow$ the use of domain-related information $\Longrightarrow$ e.g., neuron $\longrightarrow$ feature ?
    - compositionality
  - verification for generalisation and understanding



How to utilise interpretation in verification?

- Process Assurance and Certification
  - not only for the final product but also for the development cycle: data collection, model construction, training, system integration, etc
  - a successful assurance case: extension of safety argument method and goal structuring notation





- for both V&V and engineering based certification
  - for real-time learning system, we need Runtime Monitoring and Enforcement for operational errors
  - work with distributed learning system such as federated learning