Probabilistic Modeling of Insider Threat Detection Systems

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Outline

- Introduction to the Problem
- Quick Overview of Insider Threat Detection Systems (ITDS)
- Graphical Modeling of ITDSs
- Example Uses and Experiments

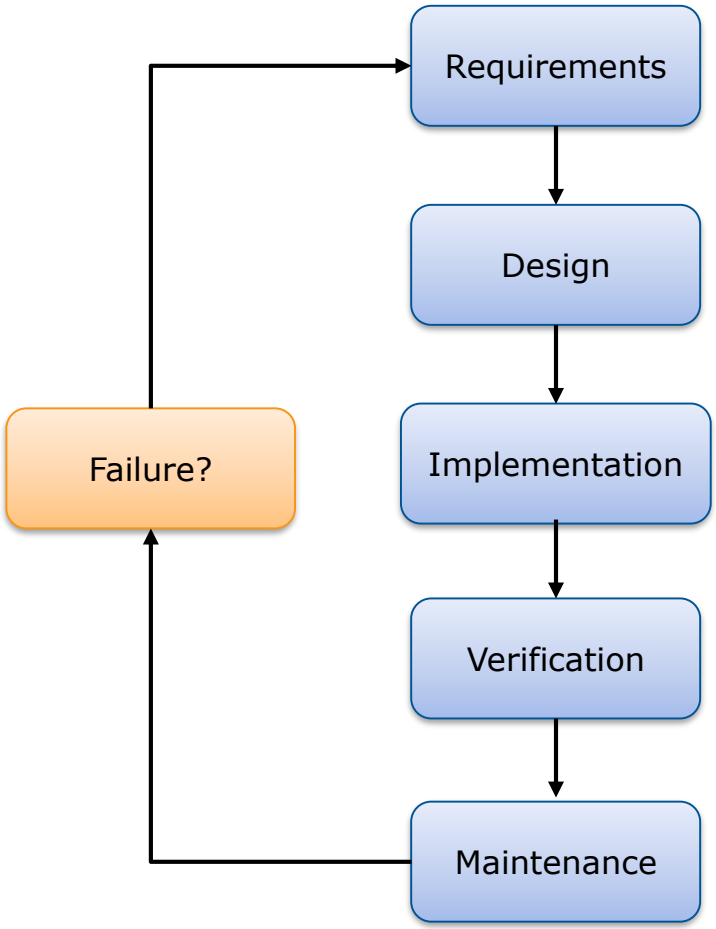
Problem Setting

- Insider threats are a major source of concern to many large organizations
  - E.g., intelligence community, Department of Defense, corporations
- Automated inference methods are the only feasible means to locate threats in these large organizations

- But these methods have many interacting parts:
  - The organization and its processes
  - People in the organization
  - Data used to support inference
  - Indicators of possible threats
  - Automated detectors of those indicators
  - Down-select algorithms to identify possible inside threats

Developing Inference Enterprises

- Implementing an Insider Threat Detection System (ITDS) is an expensive and complex procedure
  - Large number of interacting human and automated components
  - Requires lots of engineering and expensive development of IE software and the supporting infrastructure
- Highly desirable to accurately forecast IE performance *before* it is placed into operation
  - More effective threat detection
  - Understanding of weak/vulnerable points
  - Enormous time and cost savings

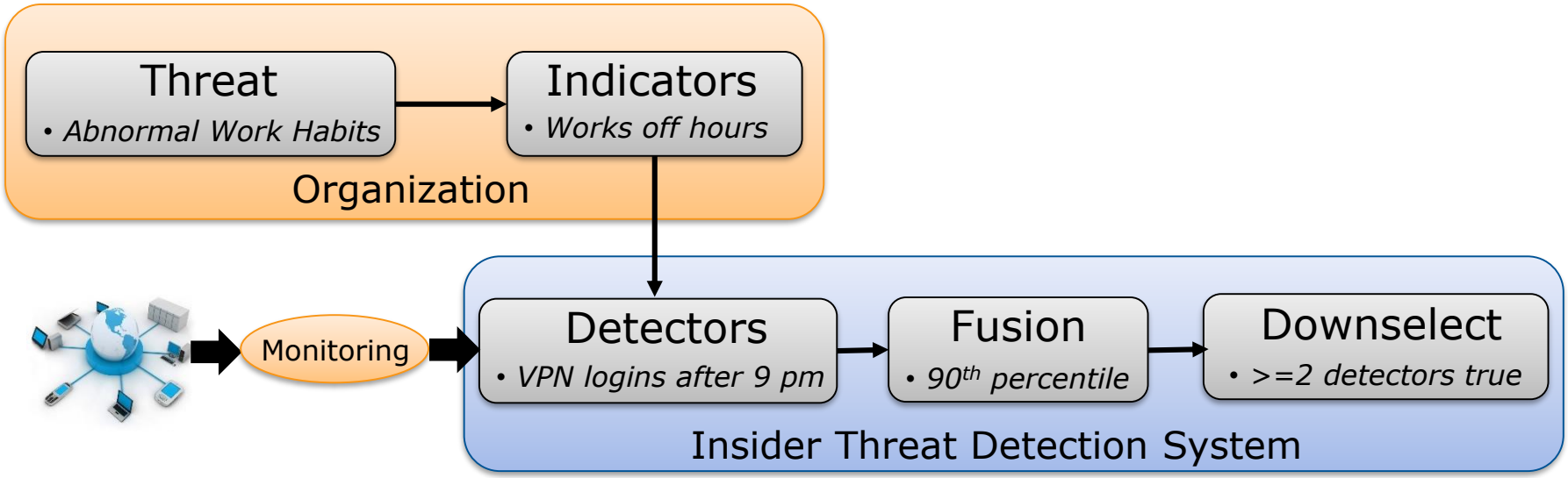


ITDS Modeling

- Modeling the performance of an ITDS *before* deployment is not small task itself!

- Many challenges include:
  - Dynamics – models must capture how organizations change over time
  - Uncertainty – raw data used for modeling might be noisy or redacted, and some parameters may be unknown
  - Complexity of ITDS components – models must capture the complex operation of detection algorithms
  - Scalability – ITDS can be large and involve many interacting components

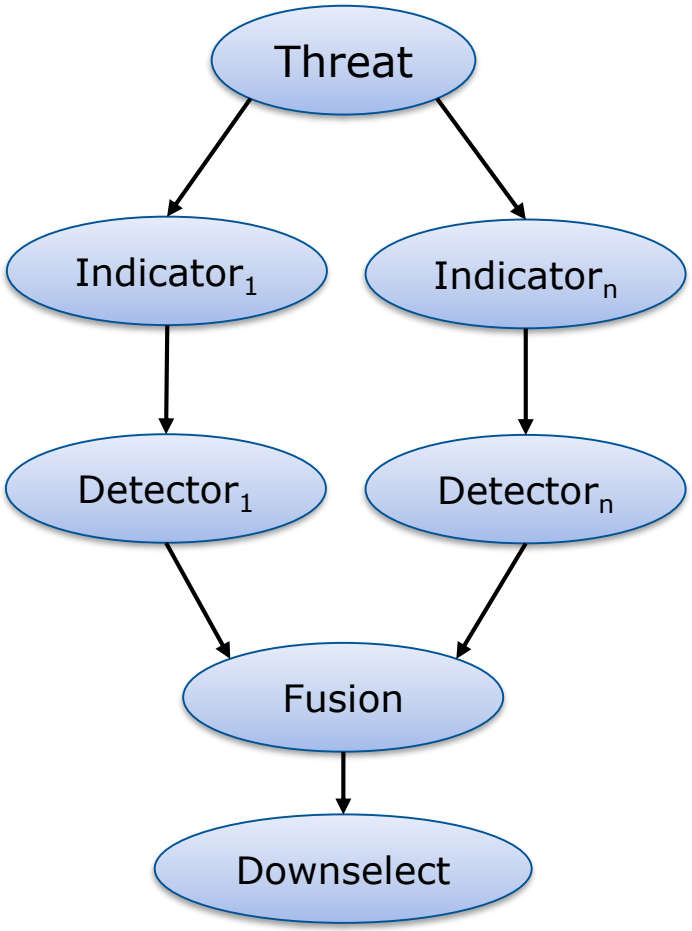
Formulation of an ITDS



- An organization contains threats and indicators of those threats
- An ITDS monitors the network infrastructure to detect for realizations of the indicators
- Data from several detectors is fused together and suspicious users are downselected for review

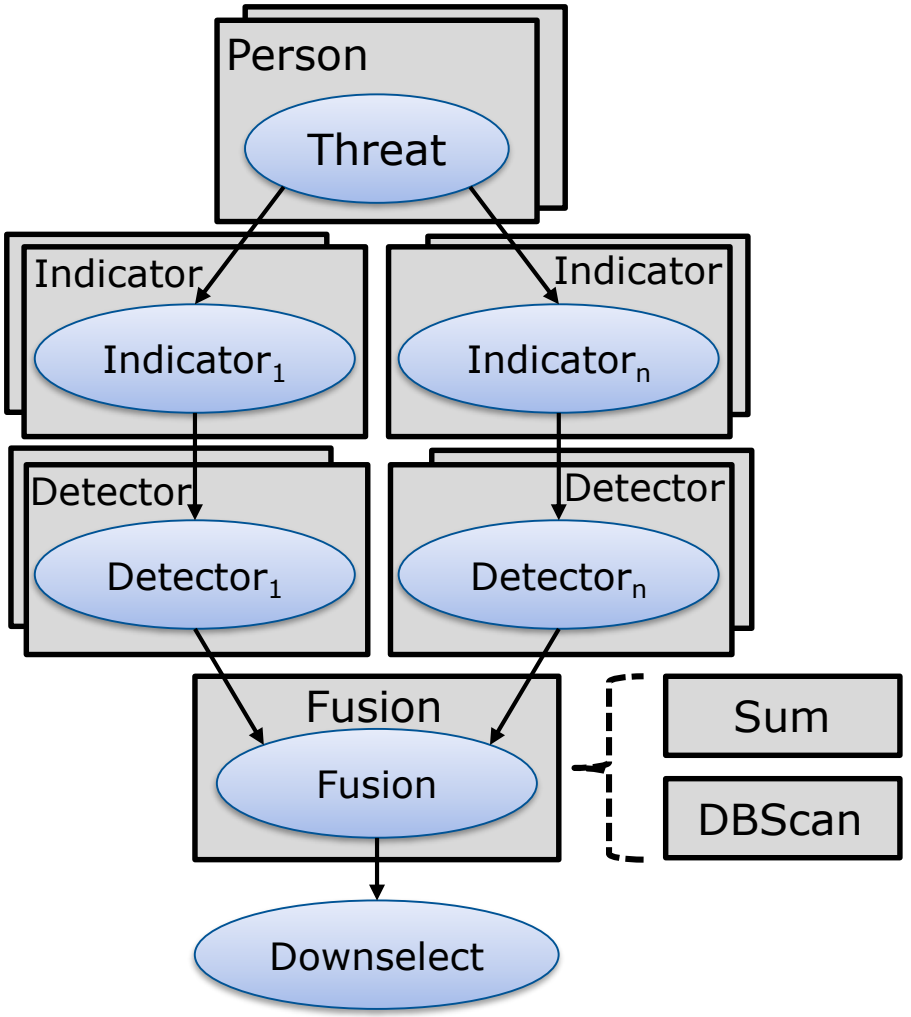
A Bayesian Network (BN) Representation of ITDS

- Convert each component of ITDS into node in BN that represents uncertainty of operation given parents
  - *Threat*: Probability of a person being a threat in the organization
  - *Indicator*: Probability of person having behavior given threat
  - *Detector*: Probability of observing the behavior in the organization
- Can augment this BN with organizational hyperpriors
  - Hyperprior over threat given different types of organizations



Implementation of ITDS Model

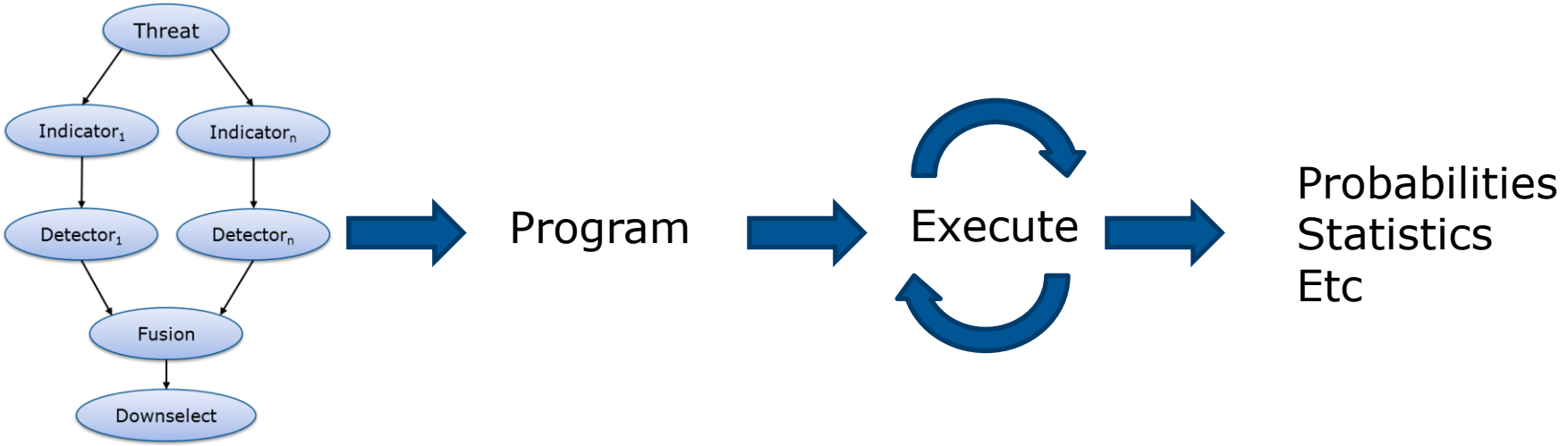
- For implementation purposes, more convenient to express model as a *probabilistic relational model* (PRM)
  - Essentially an object-oriented BN
- Easily represent uncertainty over different types of people, detectors, etc
- Can easily model groups of people at same time
- Can represent structural uncertainty



Building an ITDS Model

- Build ITDS models using *probabilistic programming* (PP)
  - Well suited to building PRMs and generalized inference on ITDS models

- PP uses programming language concepts to encode the definition of a model as a program
  - Use power of programming languages to build rich and complex decision models
  - Reasoning on the model is performed by "tracking" random executions of the program



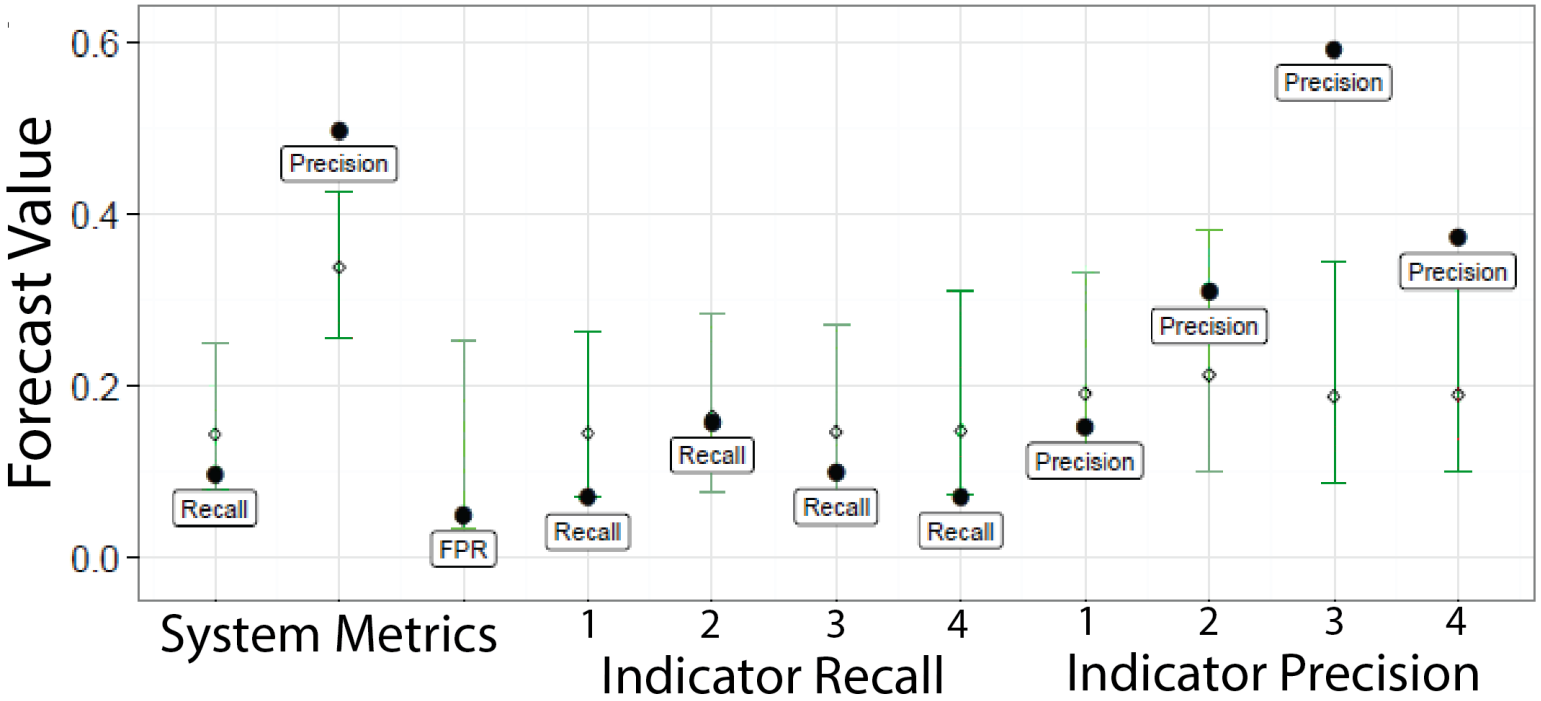
Using an ITDS Model for Analysis

- Once model is defined, built, and parameterized (with any available data), use PP inference to perform analysis

- Key advantage of PP: Same model used for many different types of inference
  - Performance estimates (marginal/joint inference)
  - Sensitivity analysis
  - Optimization (marginal-MAP, decision-making)

- Use performance metrics to drive this analysis
  - Precision, recall, false positive rate

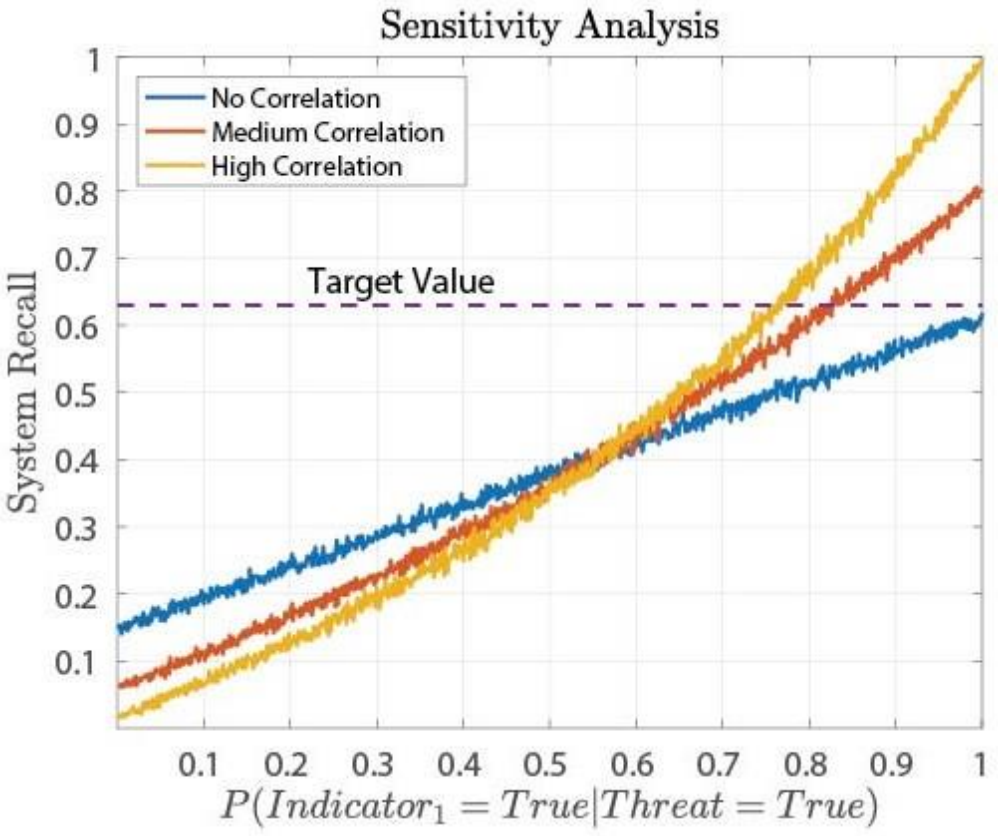
Performance Analysis



- Use marginal inference to compute distribution over metrics
- Show 60% confidence bounds on system performance
- Ground truth estimates provides by third-party evaluator

Sensitivity Analysis (SA)

- Sensitivity analysis can be used to understand implications of incorrect assumptions or changes over time
- Vary conditional probability of indicator|threat for 3 correlation models between indicators
  - Highly sensitive in this parameter
- Current research focuses on automatic differentiation methods of SA



Optimization

- Can also use model to improve design of ITDS
- Use probabilistic optimization to infer new parameter values or algorithms that maximize performance
  - Cast as a decision-making making problem to maximize utility (sum of precision and recall) by changing parameters of ITDS
- Optimization of existing ITDS (provided by third-party) nearly twice as good as the original

Decision	Component	Original Threshold	New Threshold	Utility
1	Detector A	2000	2100	1.04
2	Detector B	3	1	1.12
3	Detector C	7	8	1.14
4	Detector D	3	7	1.11
5	Detector E	1	2	1.12
6	Downselect	2	3	1.89

Conclusion

- Building an ITDS graphical model is an effective way for engineers and analysts to understand the impact of ITDSs in an organization
- Our inference capabilities provide many of the tools needed to perform this detailed and complex analysis
- Many additional issues and future work around this concept:
  - Using organizational, survey, and open-source data to parameterize models and transfer knowledge from one organization to another
  - More powerful sensitivity analysis using automatic differentiation
  - Investigating the best ITDS/model topology for different tasks

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Questions?

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