Applications of Credal Networks: Two Illustrative Examples

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Introduction

- Credal networks modeling (and solving) real problems?
  - Which kind of problems?
  - How to build the network?
  - How to solve the problem?
- Two concrete examples
  - An environmental application

    Risk analysis for a particular natural hazard
  - A military application

    Intruders **identification** for no-fly areas protection

Environmental application: debris flows hazard assessment

- Debris flows are very destructive natural hazards
- Still partially understood
- Human expertize remains fundamental!
- An artificial expert system supporting human experts?

Why a credal network?

- Why a probabilistic model?
  - Lack of a (global) deterministic model
- Why a graphical model?
  - Many **conditional independence** relations
- Why an imprecise model?
  - Deterministic equations $\Rightarrow$ Precise (degenerate) mass functions
  - Huge (and complete) datasets $\Rightarrow$ Precise mass functions
  - **Small (or incomplete) datasets** $\Rightarrow$ Credal sets
  - **Expert**'s qualitative assessments $\Rightarrow$ Credal sets

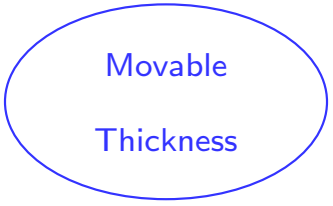
A Credal Network for debris flows

low risk $\leq 10\text{cm}$

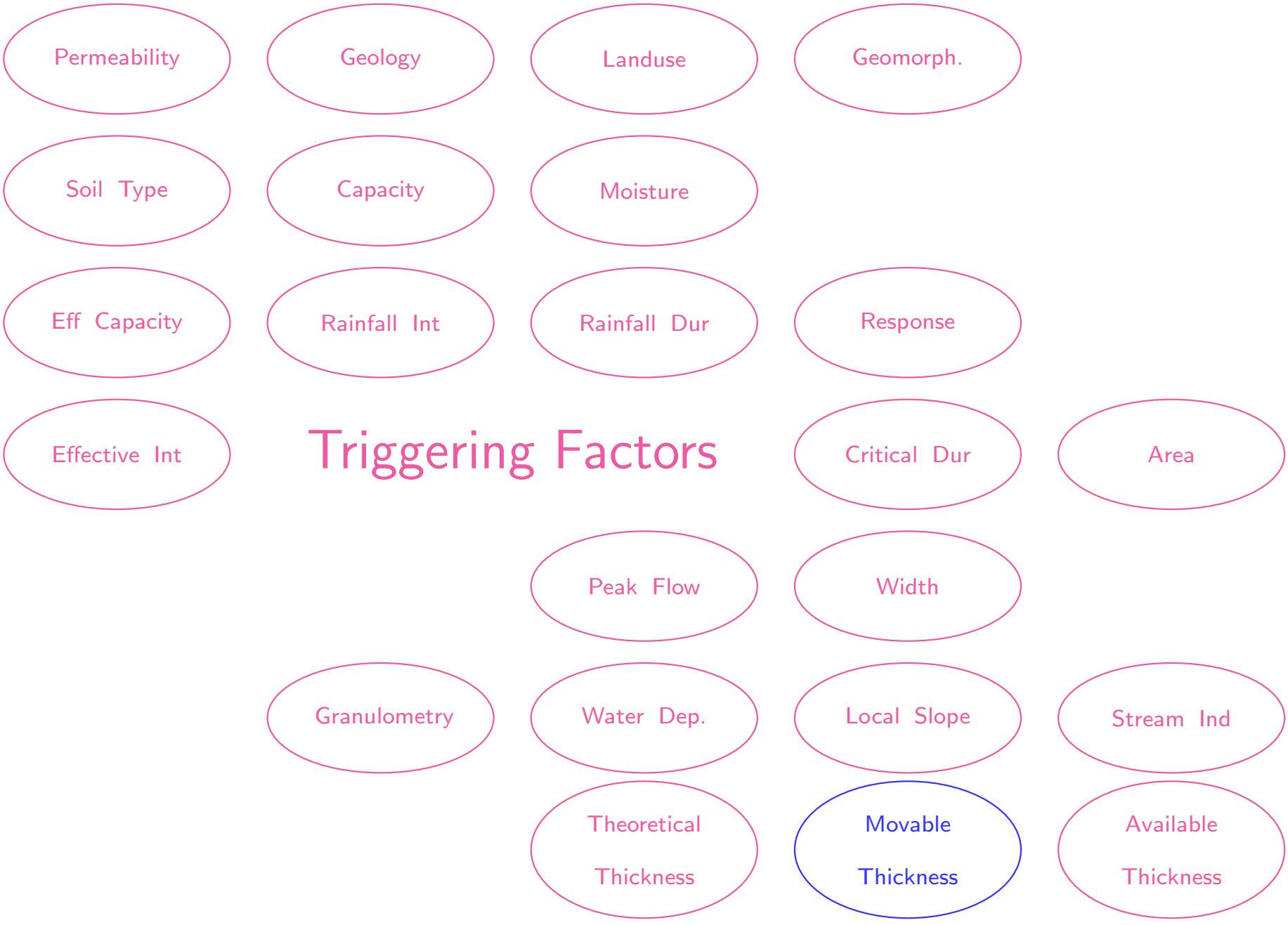
medium risk $10 - 30\text{cm}$

low risk $\geq 30\text{cm}$

Proxy indicator of the level of risk



A Credal Network for debris flows



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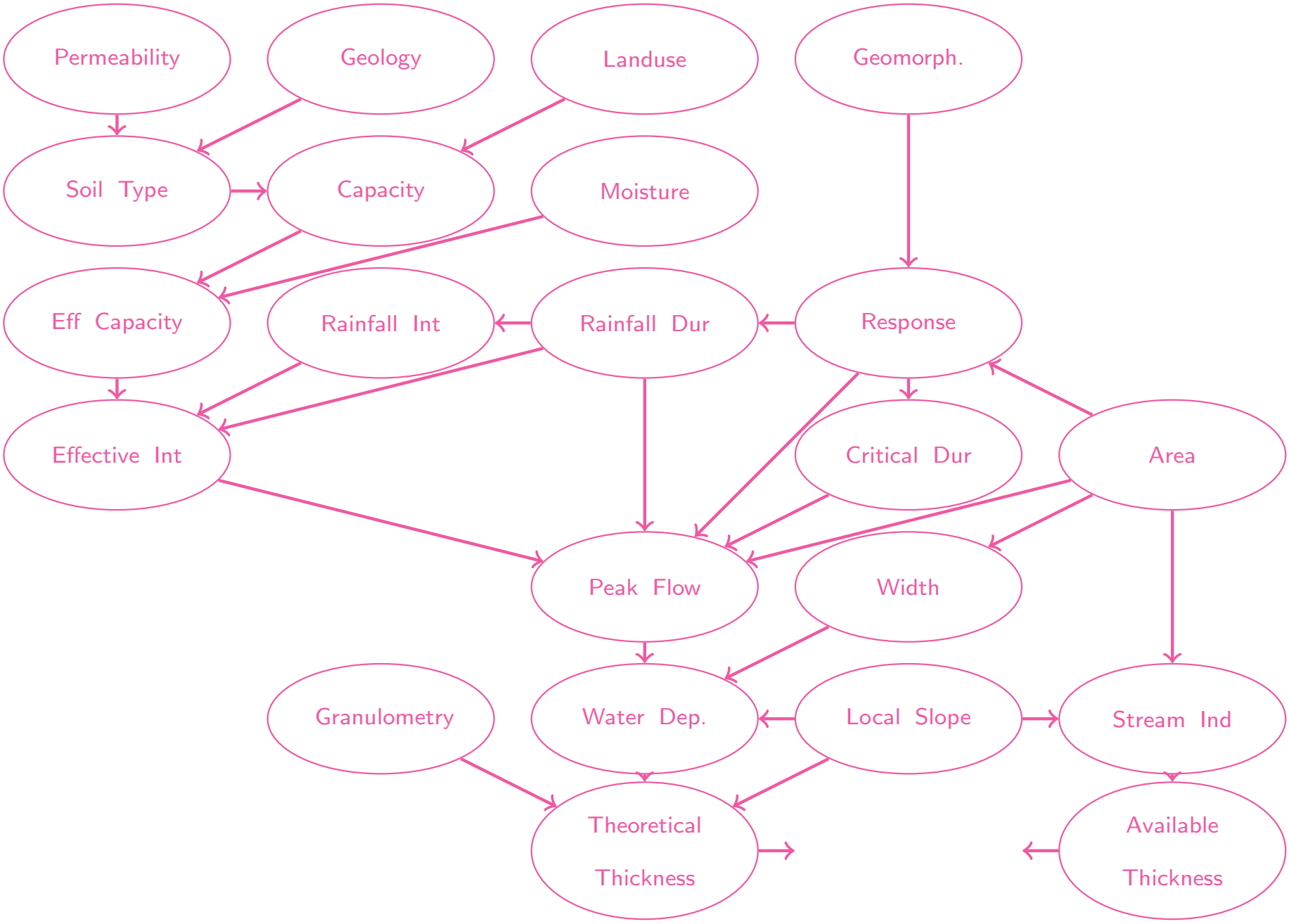
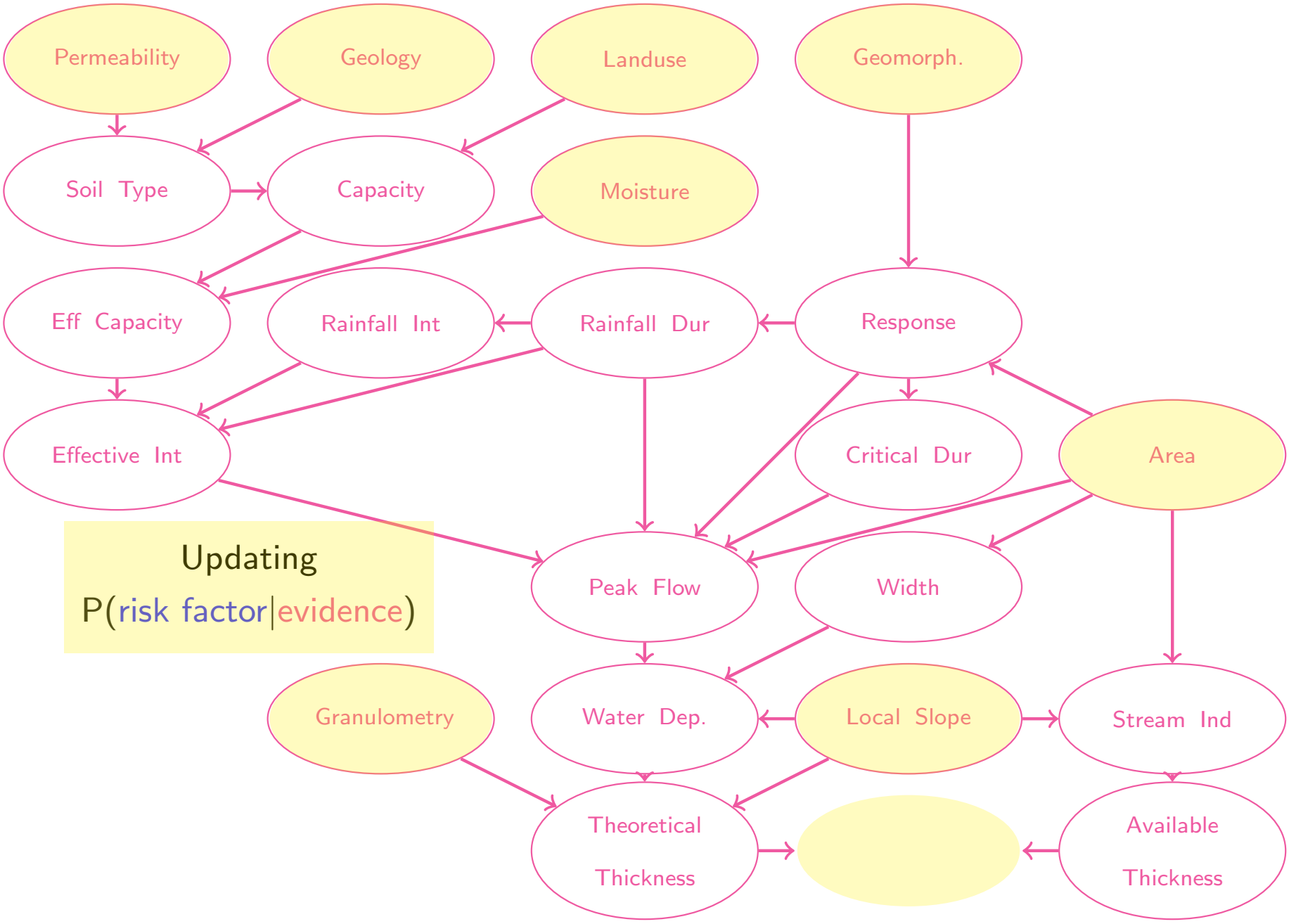
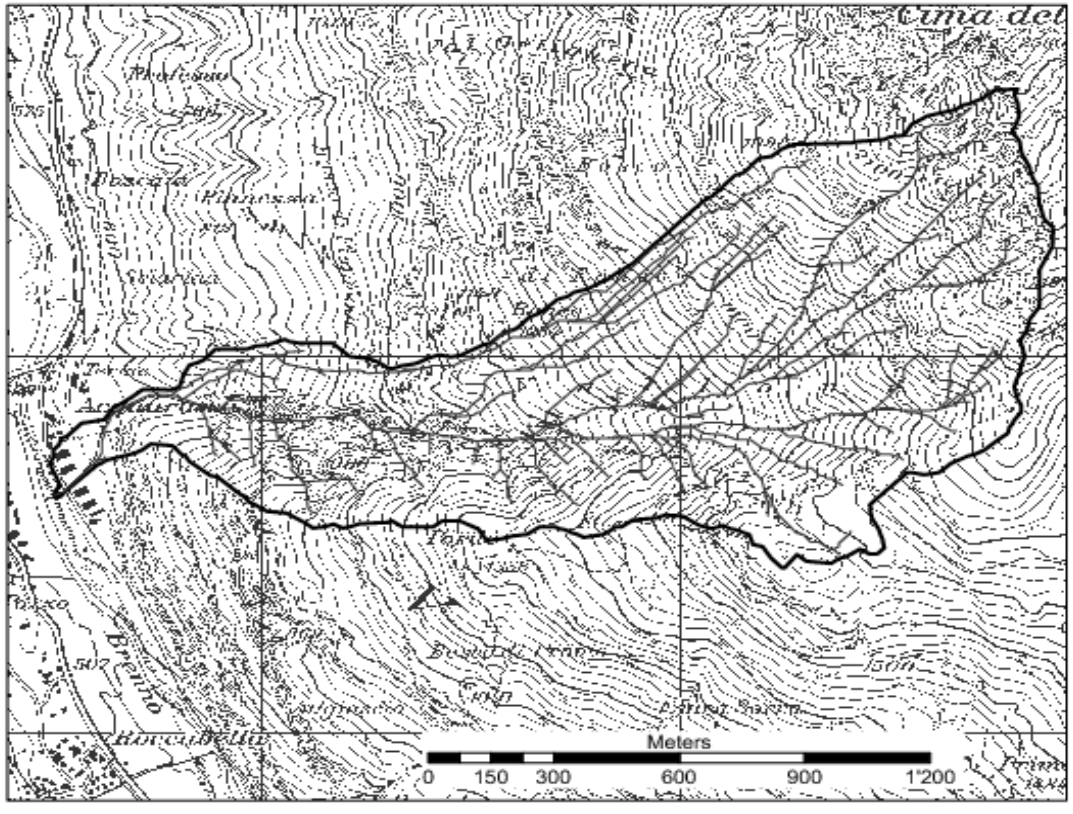


A Credal Network for debris flows



Debris flow hazard assessment by CNs

- Extensive simulations in a debris flow prone watershed



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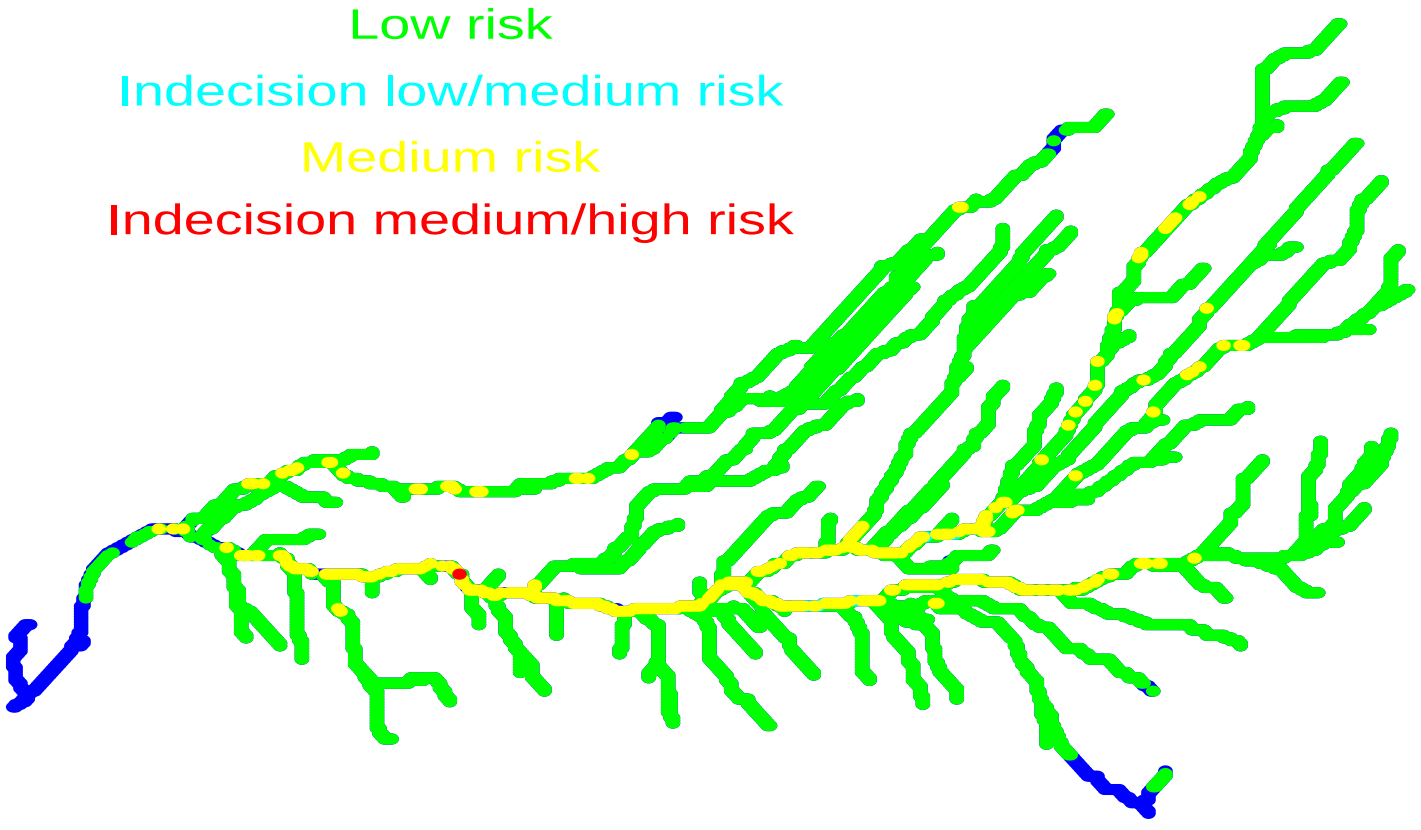

Military Application: No-fly zones protection

- Around important potential targets
  (eg. WEF, dams, nuke plants)
- Twofold circle wraps the target
  - External no-fly zone *(sensors)*
  - Internal no-fly zone *(anti-air units)*
- An aircraft entering the zone
  (aka "the intruder")
- Its presence, speed, height, and other features revealed by the sensors
- A team of military experts evaluates what the intruder intends to do

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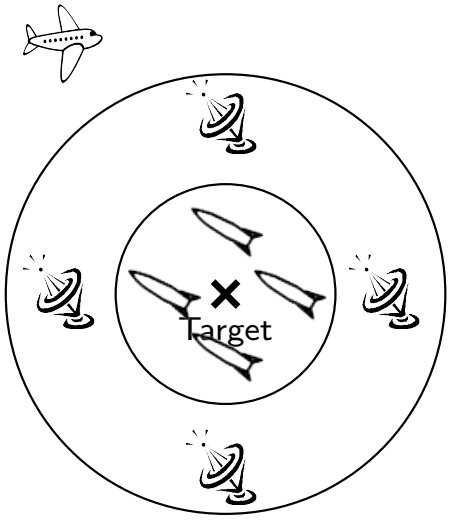
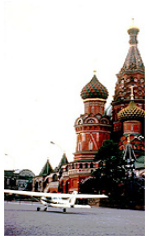


Identifying intruder's goal

- Four categorical options for intruder's goal:


renegade


provocateur

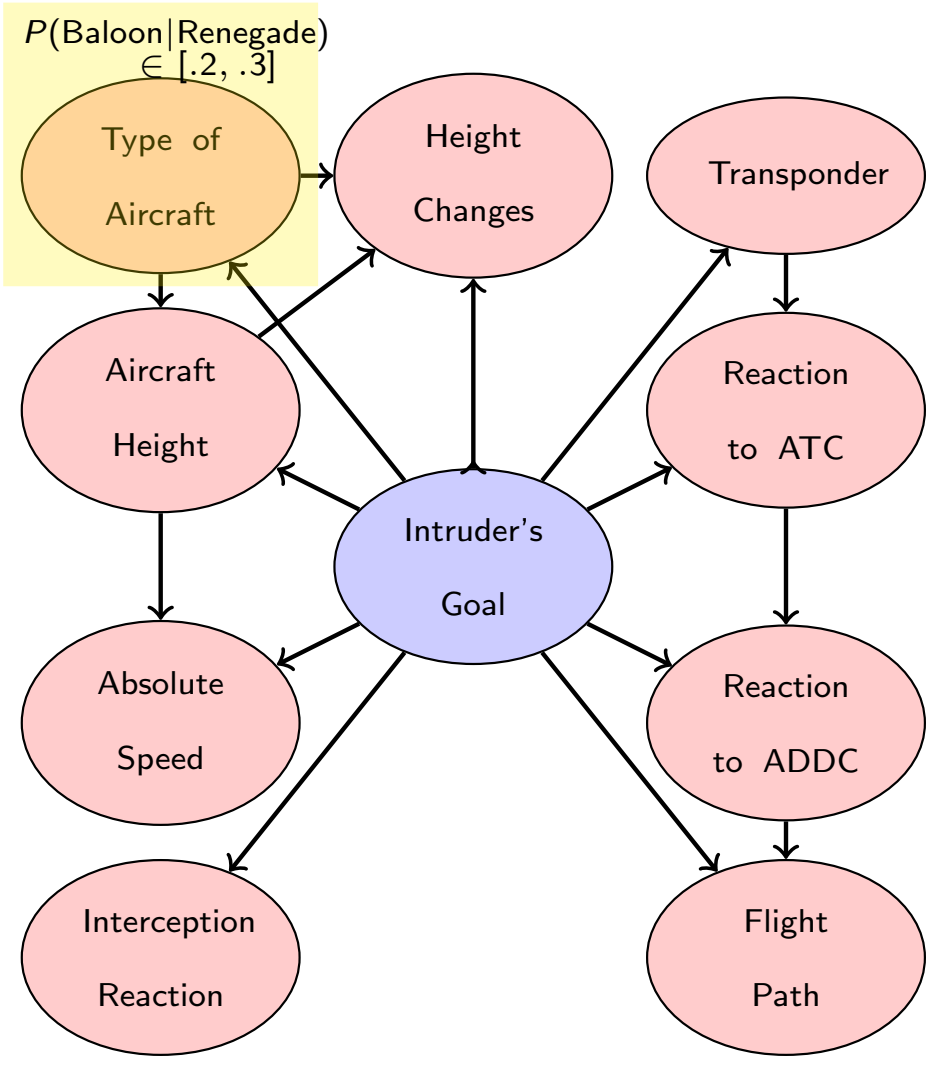

damaged


erroneous

- The identification process is difficult
  - Sensors reliabilities are affected by geo/meteo conditions
  - **Information fusion** from several sensors

Network core

- Intruder's goal and features as **categorical variables**
- Independencies depicted by a **directed graph** (acyclic)
- Experts report interval-valued probabilistic assessments, we compute **credal sets**
- A (small) **credal network**
- But the observation process of the factors is not trivial!

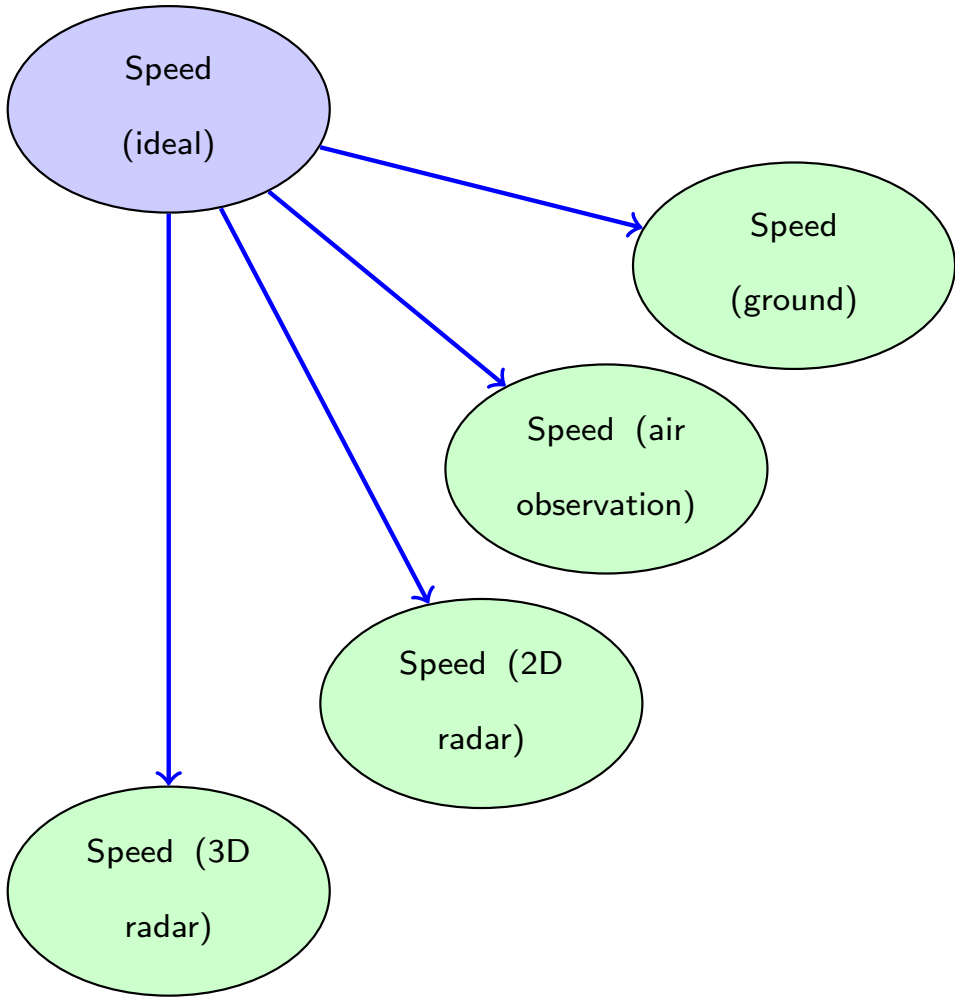


Observations Modeling and Fusion by Credal Nets

- Each sensor modeled by an auxiliary child of the (ideal) variable to be observed
- $P(\text{sensor}|\text{ideal})$ models sensor reliability

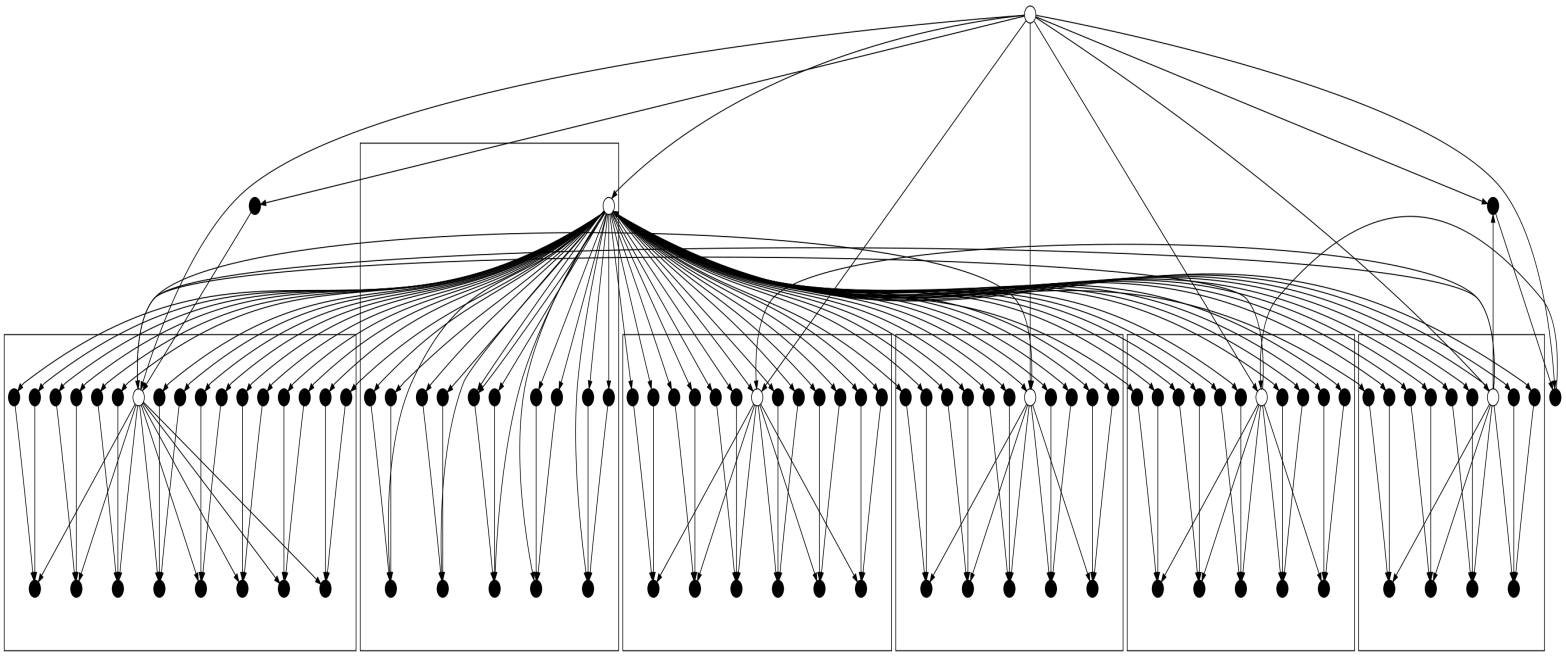
  (e.g., identity matrix = perfectly reliable sensor)
- Many sensors?
  Many children!

  (conditional independence between sensors given the ideal)



The whole network

- We conclude a huge multiply-connected credal network
- An approximate updating algorithm should be used
- GL2U *(implemented by Sun Yi)*
  [Antonucci et al., PGM 2008]



Simulations

- We can simulate scenarios, and compute the corresponding posterior intervals
- Sensors return:

  Height = very low / very low / very low / low

  Type = helicopter / helicopter

  Flight Path = U-path / U-path / U-path / U-path / U-path / missing

  Height Changes = descent / descent / descent / descent / missing

  Speed = slow / slow / slow / slow / slow

  ADDC react = positive / positive / positive / positive / positive
- *renegade* and *damaged* are rejected indecision between *provocateur* and *erroneous*
- Assuming higher levels of reliability, we conclude the aircraft is a *provocateur*!