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
Debris flows are very destructive natural hazards
Still partially understood
Human expertise 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

Proxy indicator of the level of risk

- low risk \( \leq 10 \text{cm} \)
- medium risk \( 10 - 30 \text{cm} \)
- low risk \( \geq 30 \text{cm} \)
A Credal Network for debris flows

Triggering Factors

- Permeability
- Geology
- Landuse
- Geomorph.
- Soil Type
- Capacity
- Moisture
- Rainfall Int
- Rainfall Dur
- Response
- Critical Dur
- Area
- Effective Int
- Peak Flow
- Water Dep.
- Local Slope
- Stream Ind
- Granulometry
- Theoretical Thickness
- Movable Thickness
- Available Thickness

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Triggering Factors

Updating

P(risk factor | evidence)
A Credal Network for debris flows

Triggering Factors

Updating

\[ P(\text{risk factor}|\text{evidence}) \]
Debris flow hazard assessment by CNs

- Extensive simulations in a debris flow prone watershed
Debris flow hazard assessment by CNs

- Extensive simulations in a debris flow prone watershed

Low risk
Indecision low/medium risk
Medium risk
Indecision medium/high risk
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
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!
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 / positive

- *renegade* and *damaged* are rejected

- Indecision between *provocateur* and *erroneous*

- Assuming higher levels of reliability, we conclude the aircraft is a *provocateur*!