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Covert Channels in Combinatorial Games

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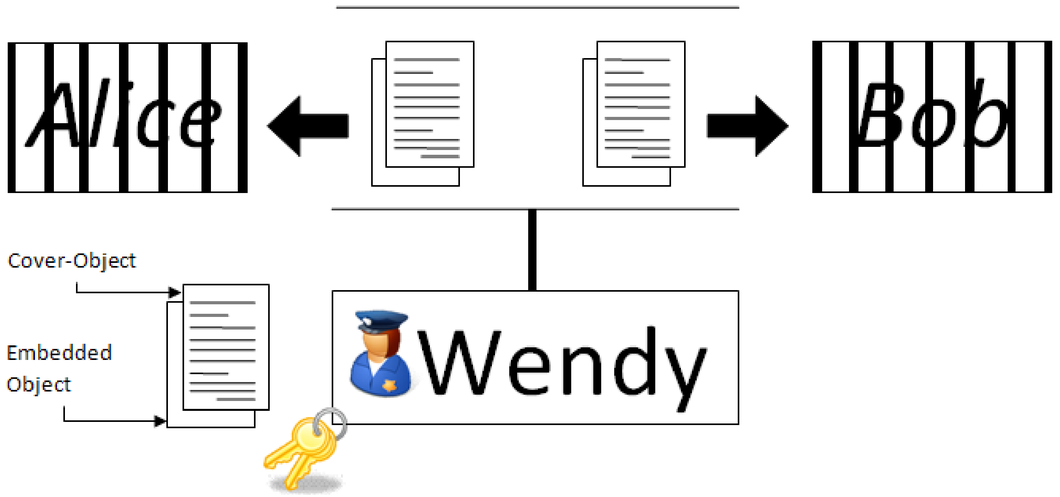
The Prisoners' Problem



Combinatorial Games

- 2 players
- Perfect Information
- No Chance Moves

Why Games?

- Dynamic
- Interactive
- Easy To Play
- Ubiquitous

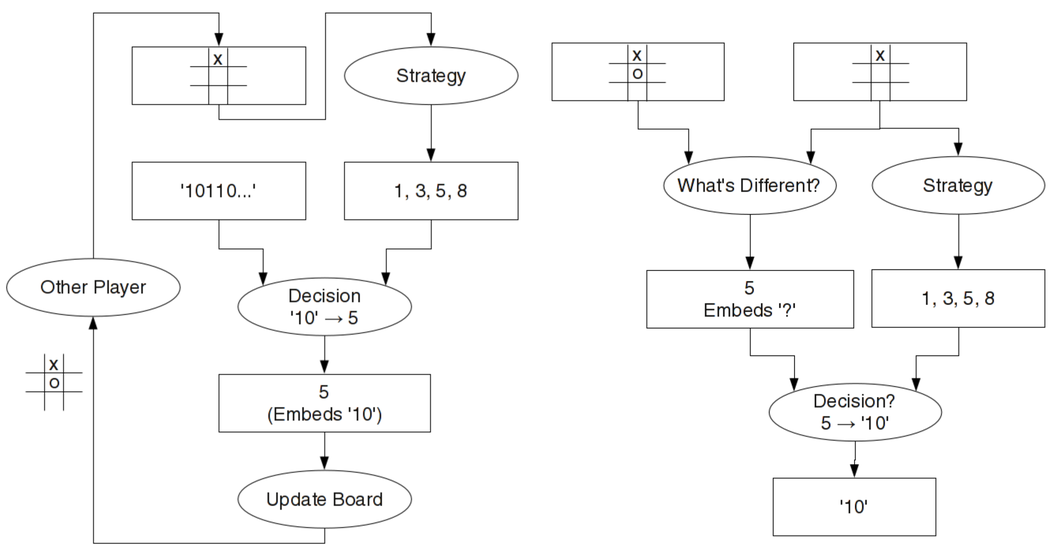
Examples:

- Angels and Devils
- Chess
- Checkers
- Chomp
- Connect-4
- Dots
- Go

…

- Tic-Tac-Toe

Methodology



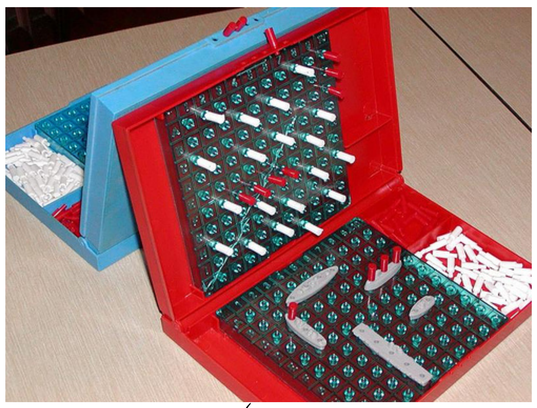
Detection Strategies

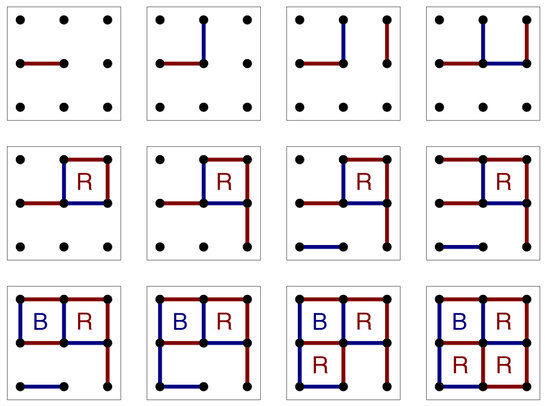
- Stupid move → suspicious
  - Mean capacity for X = 7.455 bits/game
  - Mean capacity for O = 6.650 bits/game
- Non-optimal move → suspicious
  - Mean capacity for X = 7.489 bits/game
  - Mean capacity for O = 4.326 bits/game
- Optimality out of bounds → suspicious
  - Mean capacity for X = 7.644 bits/game
  - Mean capacity for O = 5.429 bits/game
- Compare to Model of Human Gameplay
  - What model? "We're working on it!"

Other Games

$$C = \frac{1}{N} \sum_{i=1}^{2n(n-1)} [\log_2(i)]$$

C(n=10,N=2) = 506 C(n=20,N=11) = 529





$$C = \frac{1}{2} \sum_{i=100-m}^{100} [\log_2(i)]$$

C(m=16) = 51 C(m=99) = 240

$$C_P = [\log_2(1{,}925{,}751{,}392)] = 30$$

Games ~ Structured Interactions

- Why study games?
  - Generalizable
  - Human problem solving **not** well understood
  - Playing games is computationally trivial
  - Playing games *well* or *human-like* is not.
- Structured Interactions
  - N participants interacting according to a set of rules
  - Rules and actions are public
  - Captures many real-world systems
    - Network Protocols, Traffic, Natural Language, Stock Market, Negotiation.
- Anomaly Detection
  - Detecting covert channel usage is anomaly detection
  - Requires models of normal system behavior
  - How should we model human behavior?
    - Impact: Identification, Authentication, Insider Threat.

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