Cybersecurity via Signaling Games

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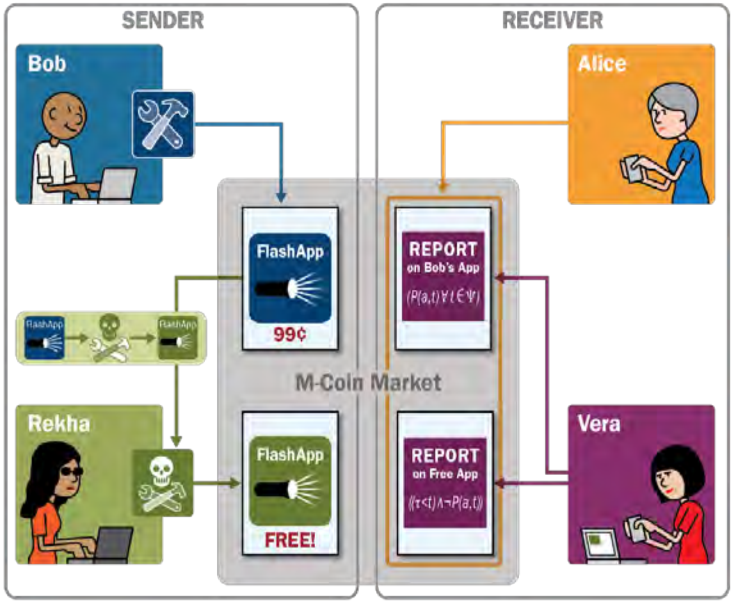
Problem: Cybersecurity

How can we establish trust, manage risk, and mitigate deceptive cyber attacks when our decision-making is constrained to partial information concerning unknowns vulnerabilities, system properties, and threats?

Our approach: A fundamental model of humans actions and the safety properties they affect.

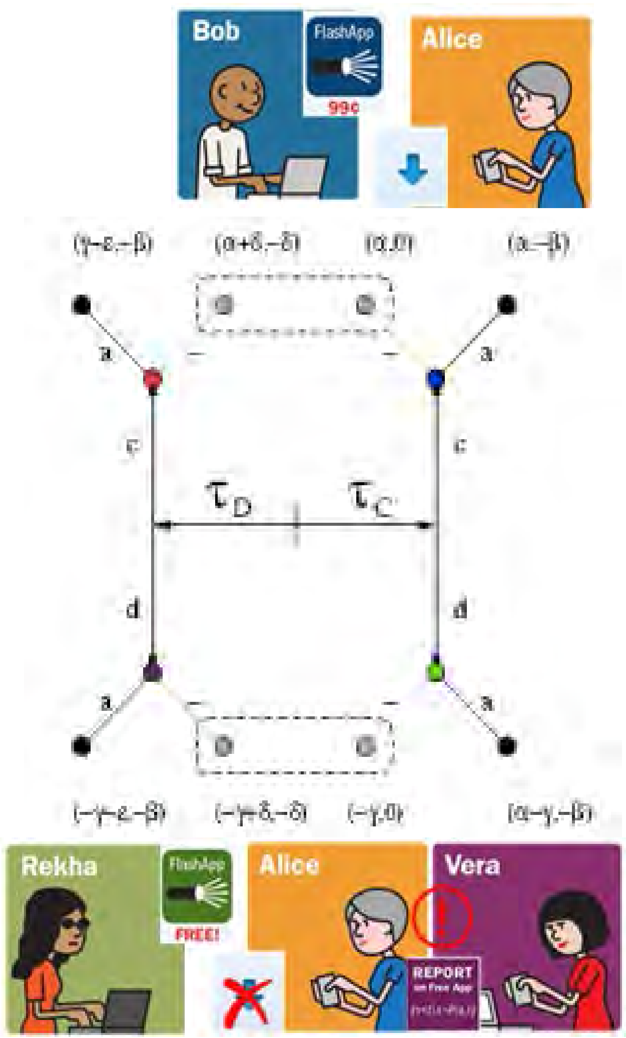
- **Game-theoretical** model to simultaneously study human and system properties within a social technological systems:
  - Deceptions are definable, allowing risk estimation and policy optimization.
  - Mathematical (and virtual) means to create, explore and design a wide range of mechanisms, including agent based models, simulation, evolutionary games, and analytic calculation of equilibria.

Cybersecurity and the Actions of People



- Information is incomplete.
  - Decisions rely on signals (info) available at the time actions are needed.
  - Deceptive strategies which leverage information asymmetries arise naturally.
- Many ways to minimize information asymmetries with respect to the desired properties of a system.
  - We organizing these into agent types:
    - Recommenders for liveness.
    - Verifiers for safety.

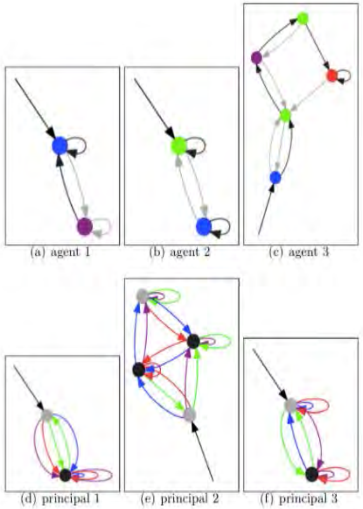
Information Asymmetric Signaling Games



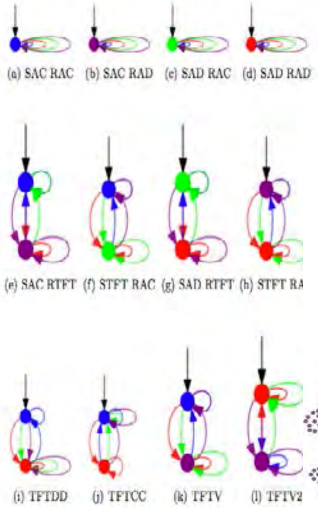
- A signaling game describes a scenario with two players:
  - A ‘sender’ has a type determined by nature and transmits a signal (information) to a ‘receiver.’
  - The ‘receiver’ having interpreted the signal selects an action with various equity outcomes – result will depend on the sender’s type (unknown), their signal, and the receiver action.
- We have specialized signaling game models to:
  - App malware.
  - Multiple vulnerabilities and deceptive exploits.
  - Managing and estimating risks from non-compliance.

Modeling Cyber and Social Technological Systems

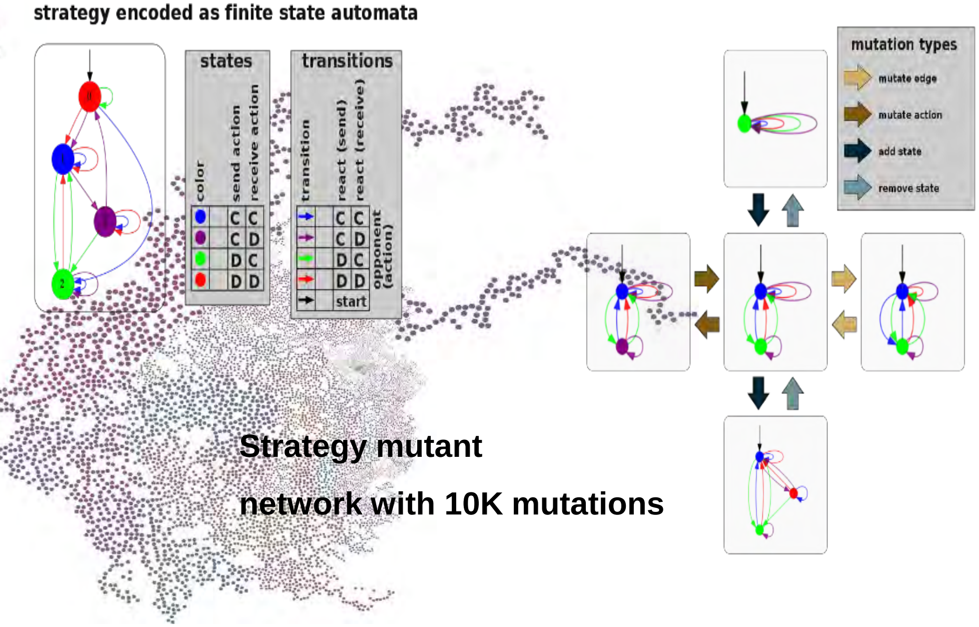
Signaling games are played repetitively in social technological systems. The **deception** or *gap between what ones says and does* is an increasingly important risk factor. We build upon evolutionary game theory (EGT) to describe systems of non-cooperative agents which explore and exploit utilities in cyber.



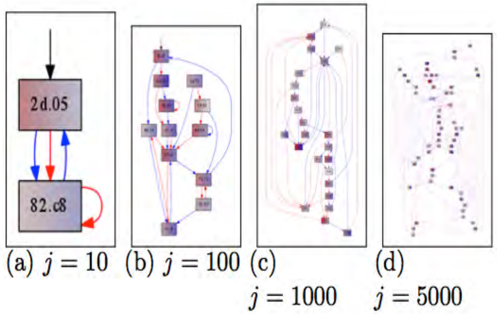
Asymmetric compliance strategies



signaling game strategies



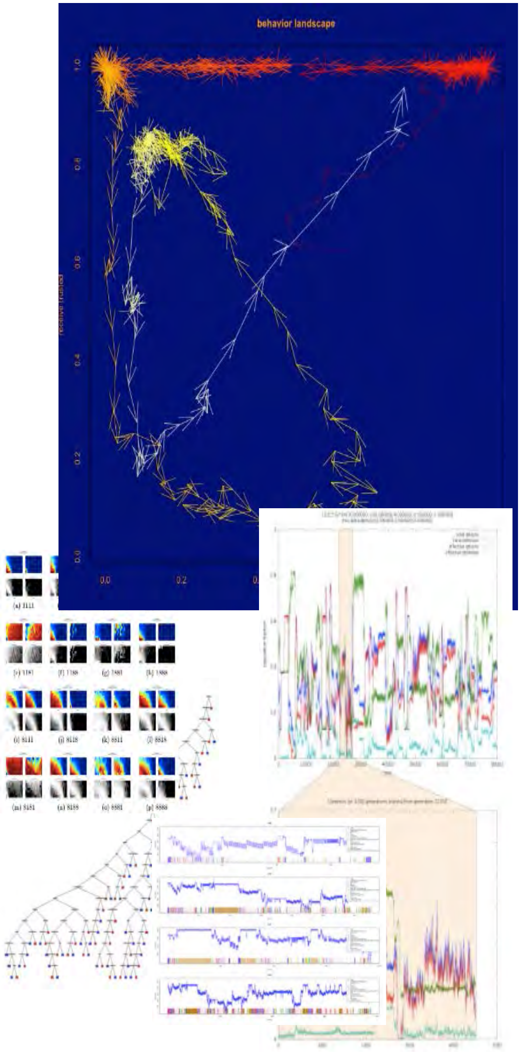
Strategy mutant network with 10K mutations



Epistatic Strategies with k-vulnerabilities

Yielding Understanding of System Dynamical Modes, Emergent Properties, Risk, and Controls

- **"Cyber Security via Signaling Games: Toward a Science of Cyber Security,"** 2014 International Conference on Distributed Computing and Internet Technology. Simulations studies reveals 'talk is cheep and costly signaling via checking market m-coin' is an effective pathway for systems recovery.
- **"Agent-Based Trace Learning in a Recommendation-Verification System for Cybersecurity,"** 2014 IEEE International Conference on Malicious and Unwanted Software. An outline of a ML defenses with a Recommendation/Verifier System that creates agent types for desired properties.
- **"Cyber Security via Minority Games with Epistatic Signaling,"** 2014 International Conference on Bio-inspired Information and Communications Technologies. Preferential early mover advantages have similar effects to maintaining strong global effectiveness measures but will be easier to do.
- <u>**Awarded Best Paper**</u>**: "Compliance Control: Managed Vulnerability Surface in Social-Technological Systems via Signaling Games,"** 2015 ACM CCS International Workshop on Managing Insider Security Threats. Consider a risk-sensitive control to actuate behavior.



Signaling Game Systems and Behavior Dynamics

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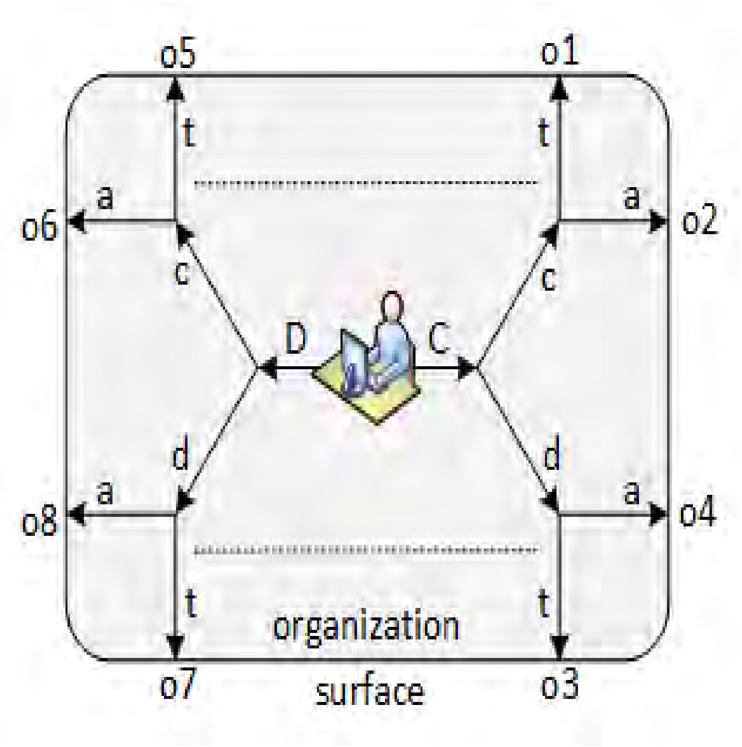
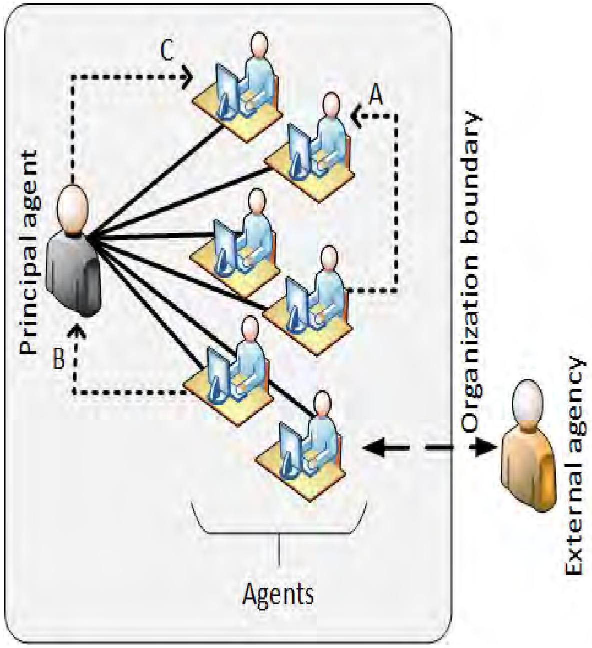
Compliance Control and Managing a Vulnerability Surface

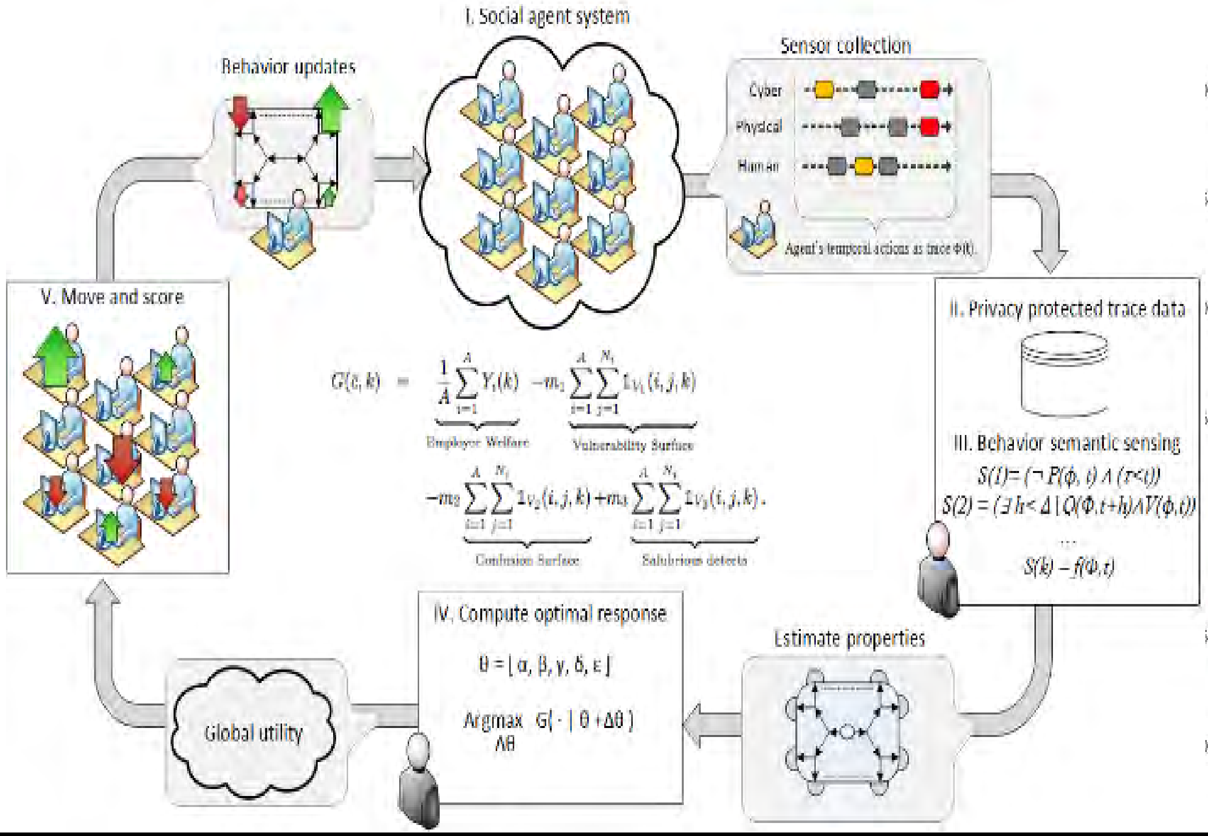
- Game focuses on organizational policies, compliance, and behavioral patterns arising from atomic actions within an organization.
- A deceptive type may optimize a local utility with a non-compliant action. Non-compliance creates vulnerability and confounds risk estimation for a principal.

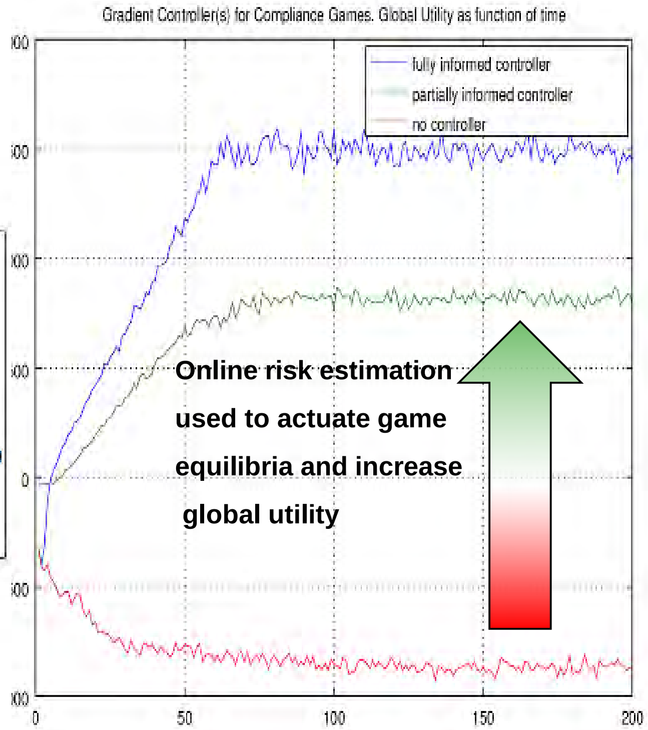




Compliance Control: Managed Vulnerability Surface

- We suggest a counter-strategy: observable risk measures with a ‘honey surface.’
- And create a closed control loop to optimize utility by forming risk estimators from observables and show that in principle: deception is a controllable.


I. Social agent system
Behavior updates
Sensor collection
Cyber
Physical
Human
Agent's temporal actions as trace Φ(t).
II. Privacy protected trace data
III. Behavior semantic sensing
$S(1)= (\neg P(\phi, t) \wedge (\tau<t))$
$S(2) = (\exists h< \Delta \mid Q(\Phi,t+h) \wedge V(\phi,t))$
...
$S(k) - f(\Phi,t)$
V. Move and score
$G(t,k) = \underbrace{\frac{1}{A}\sum_{i=1}^{A} Y_i(k)}_{\text{Employee Welfare}} - m_1 \underbrace{\sum_{i=1}^{A}\sum_{j=1}^{N_1} 1_{V_1}(i,j,k)}_{\text{Vulnerability Surface}} - m_2 \underbrace{\sum_{i=1}^{A}\sum_{j=1}^{N_2} 1_{V_2}(i,j,k)}_{\text{Confusion Surface}} + m_3 \underbrace{\sum_{i=1}^{A}\sum_{j=1}^{N_3} 1_{V_3}(i,j,k)}_{\text{Salubrious defects}}.$
IV. Compute optimal response
θ = [α, β, γ, δ, ε]
Argmax G[· | θ + Δθ]
Δθ
Estimate properties
Global utility



Online risk estimation used to actuate game equilibria and increase global utility

The end, thank you for your interest.

Question?

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