AI for Social Good: Decision aids for Countering Terrorism, Extinction, Homelessness

MILIND TAMBE

Founding Co-director, Center for Artificial Intelligence in Society (CAIS)
University of Southern California
tambe@usc.edu

Co-Founder, Avata Intelligence
AI and Multiagent Systems Research for Social Good

Public Safety and Security

Conservation

Public Health

Date: 12/3/18
Viewing Social Problems as Multiagent Systems

Key research challenge across problem areas:

Optimize Our Limited Intervention Resources when Interacting with Other Agents
Multiagent Systems
Optimizing Limited Intervention (Security) Resources

Public Safety and Security
Stackelberg Security Games

- Game Theory for security resource optimization
- Real-world: US Coast Guard, US Federal Air Marshals Service…
Multiagent Systems
Optimizing Limited Intervention (Ranger) Resources

Conservation/Wildlife Protection: Green Security Games

- Security games and adversary (poacher) behavior prediction
- Real-world: National parks in Uganda, Malaysia…
Multiagent Systems
Optimizing Limited Intervention (Messaging) Resources

Public Health Awareness:
Influence Maximization as a Game against Nature

- Social networks to enhance intervention, e.g., HIV information
- **Real-world pilot tests: Homeless youth shelters in Los Angeles**
Overall Research Framework, Partnerships and Publications

Date: 12/3/18
Outline

Public Safety and Security
Stackelberg Security Games

Conservation/Wildlife Protection
Green Security Games

Public Health
Influence maximization/Game against nature

- AAMAS, AAAI, IJCAI evaluation + Real world evaluation
- PhD students and postdocs
11 July 2006: Mumbai

**TRAIN OF TERROR**
Mumbai continues to be the prime target for terrorist groups. It has borne the brunt of seven attacks in the past 13 years.

**Explosive used**
High-quality explosives. Most likely RDX. (Oxidised nitrocellulose)

**Quantity of explosive**
At least 5 kg per blast, possibly packed into bags or tiffin boxes

**Where were bombs placed?**
In the baggage racks where commuters keep their bags and tiffin boxes

**How many bombers were there?**
At least 20; 2 for each train and a logistic team of 8 people

**Why attack the first class compartments?**
It is easier to enter at first-class compartments at peak hour than a second-class with a bag filled with up to 5 kg of explosives

---

**WARNING**

**JAN 4, 2003**
12 bomb blasts in trains near Thane, three youths from Palghar arrested.

**JAN 30, 2006**
Four bomb blasts in trains near Thane, 12 arrests.

**FEB 5, 2006**
Two bomb blasts in trains near Thane, 35 arrests.

**MAY 12, 2006**
Three NSG commandos killed in a grenade attack on an RPF vehicle near Andheri, Thane.

---

**Date: 12/3/18**
ARMOR Airport Security: LAX(2007) Game Theory direct use for security resource optimization?

Erroll Southers

LAX Airport, Los Angeles

Glasgow: June 30, 2007

Date: 12/3/18
Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games, key aspects for tractability

Set of targets, payoffs based on targets covered or not
Stackelberg Leader-Follower formulation

<table>
<thead>
<tr>
<th></th>
<th>Terminal #1</th>
<th>Terminal #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal #1</td>
<td>4, -3</td>
<td>-1, 1</td>
</tr>
<tr>
<td>Terminal #2</td>
<td>-5, 5</td>
<td>2, -1</td>
</tr>
</tbody>
</table>
Model: Stackelberg Security Games

**Stackelberg:** Defender commits to randomized strategy, adversary responds

**Security optimization:** Not 100% security; increase cost/uncertainty to attackers

**Challenges faced:** Massive scale games

<table>
<thead>
<tr>
<th></th>
<th>Terminal #1</th>
<th>Terminal #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal #1</td>
<td>4, -3</td>
<td>-1, 1</td>
</tr>
<tr>
<td>Terminal #2</td>
<td>-5, 5</td>
<td>2, -1</td>
</tr>
</tbody>
</table>
ARMOR at LAX
Basic Security Game Operation [2007]

<table>
<thead>
<tr>
<th>Target #1</th>
<th>Target #2</th>
<th>Target #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defender #1</td>
<td>2, -1</td>
<td>-3, 4</td>
</tr>
<tr>
<td>Defender #2</td>
<td>-3, 3</td>
<td>3, -2</td>
</tr>
<tr>
<td>Defender #3</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

Mixed Integer Program

Pr (Canine patrol, 8 AM @Terminals 2,5,6) = 0.17

Canine Team Schedule, July 28

<table>
<thead>
<tr>
<th>Term 1</th>
<th>Term 2</th>
<th>Term 3</th>
<th>Term 4</th>
<th>Term 5</th>
<th>Term 6</th>
<th>Term 7</th>
<th>Term 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 AM</td>
<td>Team1</td>
<td></td>
<td></td>
<td>Team3</td>
<td>Team5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 AM</td>
<td></td>
<td>Team1</td>
<td>Team2</td>
<td></td>
<td></td>
<td>Team4</td>
<td></td>
</tr>
<tr>
<td>....</td>
<td>....</td>
<td>....</td>
<td>....</td>
<td>....</td>
<td>....</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>
Security Game MIP [2007]

\[
\text{max } \sum_{i \in X} \sum_{j \in Q} R_{ij} \times x_i \times q_j
\]

\[
s.t. \quad \sum_{i} x_i = 1
\]

\[
\sum_{j \in Q} q_j = 1
\]

\[
0 \leq (a - \sum_{i \in X} C_{ij} x_i) \leq (1 - q_j) M
\]

Target #1 | Target #2 | Target #3
--- | --- | ---
Defender #1 | 2, -1 | -3, 4 | -3, 4
Defender #2 | -3, 3 | 3, -2 | ....
Defender #3 | .... | .... | ....

Maximize defender expected utility
Defender mixed strategy
Adversary response
Adversary best response

Date: 12/3/18
SECURITY GAME PAYOFFS [2007]
Previous Research Provides Payoffs in Security Games

<table>
<thead>
<tr>
<th>Defenders</th>
<th>Target #1</th>
<th>Target #2</th>
<th>Target #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defender #1</td>
<td>2, -1</td>
<td>-3, 4</td>
<td>-3, 4</td>
</tr>
<tr>
<td>Defender #2</td>
<td>-3, 3</td>
<td>3, -2</td>
<td>....</td>
</tr>
<tr>
<td>Defender #3</td>
<td>....</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

\[ \max \sum_{i \in X} \sum_{j \in Q} R_{ij} \times x_i \times q_j \]

Maximize defender expected utility

+ Handling Uncertainty
ARMOR:
Optimizing Security Resource Allocation [2007]

First application: Computational game theory for operational security

Date: 12/3/18

January 2009

• January 3rd
• January 9th
• January 10th
• January 12th
• January 17th
• January 22nd

16-Handguns, 1000 rounds of ammo
Two unloaded shotguns
Loaded 22/cal rifle
Loaded 9/mm pistol
Unloaded 9/mm pistol

Date: 12/3/18
ARMOR AIRPORT SECURITY: LAX [2008]
Congressional Subcommittee Hearings

Commendations
City of Los Angeles

Erroll Southers testimony
Congressional subcommittee

ARMOR…throws a digital cloak of invisibility….
Federal Air Marshals Service [2009]

Visiting Freedom Center: Home of Federal Air Marshals Service

Date: 12/3/18

IRIS 1000 flights/day
Actions: $\sim 10^{41}$
Scale Up Difficulty [2009]

\( x_i \) Defender mixed strategy

\[
\max_{x,q} \sum_{i \in X} \sum_{j \in Q} R_{ij} x_i q_j
\]

s.t. \( \sum_i x_i = 1, \sum_j q_j = 1 \)

\[
0 \leq (a - \sum_{i \in X} C_{ij} x_i) \leq (1 - q_j)M
\]

1000 flights, 20 air marshals:

\( 10^{41} \) combinations

<table>
<thead>
<tr>
<th>Attack 1</th>
<th>Attack 2</th>
<th>Attack ...</th>
<th>Attack 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3 ..</td>
<td>5, -10</td>
<td>4, -8</td>
<td>...</td>
</tr>
<tr>
<td>1, 2, 4 ..</td>
<td>5, -10</td>
<td>4, -8</td>
<td>...</td>
</tr>
<tr>
<td>1, 3, 5 ..</td>
<td>5, -10</td>
<td>-9, 5</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>10^{41} rows</td>
<td>...</td>
</tr>
</tbody>
</table>
Scale Up [2009]
Exploiting Small Support Size

Theorem: For T targets, solutions exist where support set size is $T+1$

Small support set size: Most $x_i$ variables zero

1000 flights, 20 air marshals:
$10^{41}$ combinations

<table>
<thead>
<tr>
<th>Attack 1</th>
<th>Attack 2</th>
<th>Attack $\ldots$</th>
<th>Attack 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3 ..</td>
<td>5, 10</td>
<td>4, 9</td>
<td>...</td>
</tr>
<tr>
<td>1, 2, 4 ..</td>
<td>5, -10</td>
<td>4, -8</td>
<td>...</td>
</tr>
<tr>
<td>1, 3, 5 ..</td>
<td>5, 10</td>
<td>9, 5</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>10^{41} rows</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
New Exact Algorithm for Scale up

**Incremental strategy generation:** First for Stackelberg Security Games

### Master

<table>
<thead>
<tr>
<th></th>
<th>Attack 1</th>
<th>Attack 2</th>
<th>...</th>
<th>Attack 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2,4</td>
<td>5,-10</td>
<td>4,-8</td>
<td>...</td>
<td>-20,9</td>
</tr>
<tr>
<td>1,2,4</td>
<td>5,-10</td>
<td>4,-8</td>
<td>...</td>
<td>-20,9</td>
</tr>
<tr>
<td>3,7,8</td>
<td>-8,10</td>
<td>-8,10</td>
<td>...</td>
<td>-8,10</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

### Slave (LP Duality Theory)

- **Best new pure strategy**
- **Global optimal**

1000 defender strategies

**NOT** $10^{41}$
IRIS: Deployed FAMS [2009-]

Significant change in FAMS operations

September 2011: Certificate of Appreciation (Federal Air Marshals)
Road networks:
20,000 roads, 15 checkpoints

150 edges
2 Checkpoints
150-choose-2 strategies
**Double oracle**: New exact optimal algorithm for scale-up

### Zero-Sum Network Security Game [2013]

#### Defender oracle

<table>
<thead>
<tr>
<th></th>
<th>Path #1</th>
<th>Path #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checkpoint strategy #1</td>
<td>5, -5</td>
<td>-1, 1</td>
</tr>
<tr>
<td>Checkpoint strategy #2</td>
<td>-5, 5</td>
<td>1, -1</td>
</tr>
</tbody>
</table>

#### Attacker oracle

<table>
<thead>
<tr>
<th></th>
<th>Path #1</th>
<th>Path #2</th>
<th>Path #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checkpoint strategy #1</td>
<td>5, -5</td>
<td>-1, 1</td>
<td>-2, 2</td>
</tr>
<tr>
<td>Checkpoint strategy #2</td>
<td>-5, 5</td>
<td>1, -1</td>
<td>-2, 2</td>
</tr>
</tbody>
</table>
Presentation at the Indian National Police Academy: Network Security Game [2016]

Road networks:
20,000 roads, 15 checkpoint: *Solved under 20 min*
PROTECT: Port and Ferry Protection Patrols [2011] Using Marginals for Scale up

Boston

Los Angeles

New York

Date: 12/3/18
**Marginal strategy:** New scale-up approach for Stackelberg Security Games
Date: 12/3/18

FERRIES: Mobile Resources & Moving Targets
Transition Graph Representation

<table>
<thead>
<tr>
<th></th>
<th>5 min</th>
<th>10 min</th>
<th>15 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, 5 min</td>
<td>A, 10 min</td>
<td>A, 15 min</td>
</tr>
<tr>
<td>B</td>
<td>B, 5 min</td>
<td>B, 10 min</td>
<td>B, 15 min</td>
</tr>
<tr>
<td>C</td>
<td>C, 5 min</td>
<td>C, 10 min</td>
<td>C, 15 min</td>
</tr>
</tbody>
</table>

Ferry
FERRIES: Mobile Resources & Moving Targets
Transition Graph Representation

Patrol protects nearby ferry locations

<table>
<thead>
<tr>
<th></th>
<th>5 min</th>
<th>10 min</th>
<th>15 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, 5 min</td>
<td>A, 10 min</td>
<td>A, 15 min</td>
</tr>
<tr>
<td>B</td>
<td>B, 5 min</td>
<td>B, 10 min</td>
<td>B, 15 min</td>
</tr>
<tr>
<td>C</td>
<td>C, 5 min</td>
<td>C, 10 min</td>
<td>C, 15 min</td>
</tr>
</tbody>
</table>

Ferry
Patrol

Date: 12/3/18
FERRIES: Mobile Resources & Moving Targets
Transition Graph Representation

Date: 12/3/18
FERRIES: Mobile Resources & Moving Targets Transition Graph Representation

ARMOR style LP: Determine probability for each route

<table>
<thead>
<tr>
<th></th>
<th>5 min</th>
<th>10 min</th>
<th>15 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, 5 min</td>
<td>A, 10 min</td>
<td>A, 15 min</td>
</tr>
<tr>
<td>B</td>
<td>B, 5 min</td>
<td>B, 10 min</td>
<td>B, 15 min</td>
</tr>
<tr>
<td>C</td>
<td>C, 5 min</td>
<td>C, 10 min</td>
<td>C, 15 min</td>
</tr>
</tbody>
</table>

Date: 12/3/18
Variables: NOT routes, but marginal probability over each segment
Theorem: Marginal representation does not lose any solution quality

Extract: $\Pr((B,5), (C,10), (C,15)) = 0.47$
\[\Pr((B,5), (C,10), (B,15)) = 0.23\]
PROTECT: Port Protection Patrols [2013]
Congressional Subcommittee Hearing

June 2013: Meritorious Team Commendation from Commandant (US Coast Guard)

July 2011: Operational Excellence Award (US Coast Guard, Boston)
# Train Patrols

**Execution Uncertainty: MDPs**

<table>
<thead>
<tr>
<th></th>
<th>5 min</th>
<th>10 min</th>
<th>15 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, 5 min</td>
<td>A, 10 min</td>
<td>A, 15 min</td>
</tr>
<tr>
<td>B</td>
<td>B, 5 min</td>
<td>B, 10 min</td>
<td>B, 15 min</td>
</tr>
<tr>
<td>C</td>
<td>C, 5 min</td>
<td>C, 10 min</td>
<td>C, 15 min</td>
</tr>
</tbody>
</table>

Date: 12/3/18
Handling Payoff Uncertainty: Optimal Defender Strategy Minimizing Max Regret

- **Payoff uncertainty**

- **DefenderUtility(c):** -2.3
- **Optimal utility:** 0.4
- **Regret (c, payoff):** 2.7

<table>
<thead>
<tr>
<th>Adversary</th>
<th>Target #1</th>
<th>Target #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target #1</td>
<td>4, [-4,-2]</td>
<td>-1, [0,2]</td>
</tr>
<tr>
<td>Target #2</td>
<td>-5, [4,6]</td>
<td>2, [-2,0]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Defender</th>
<th>Target #1</th>
<th>Target #2</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target #1</td>
<td>4, -3</td>
<td>-1, 1</td>
<td>0.3</td>
</tr>
<tr>
<td>Target #2</td>
<td>-5, 5</td>
<td>2, -2</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Minimizing Maximum Regret: New Iterative Constraint Generation Algorithm

\[
\min_{c, r} r \quad \text{where } r \geq \text{regret}(c, \text{payoff}), \forall \text{payoff} \in \text{Interval}
\]

Master: Compute Lower Bound

Minimax Regret with sample set of attacker payoffs

Slave: Compute Upper Bound

New attacker payoff causing max regret

Date: 12/3/18
Evaluating Deployed Security Systems Not Easy

How Well Optimized Use of Limited Security Resources?

Security Games superior
vs
Human Schedulers/”simple random”

- Lab evaluation
- *Scheduling competitions: Patrol quality unpredictability? Coverage?*
- Field evaluation: Tests against real adversaries
- *Economic cost-benefit analysis*
- …
Field Evaluation of Schedule Quality

Improved Patrol Unpredictability & Coverage for Less Effort

Patrols Before PROTECT: Boston

Patrols After PROTECT: Boston

350% increase in defender expected utility

Date: 12/3/18
Field Evaluation of Schedule Quality

Improved Patrol Unpredictability & Coverage for Less Effort

**FAMS:** IRIS Outperformed expert human over six months

Report: GAO-09-903T

**Trains:** TRUSTS outperformed expert humans schedule 90 officers on LA trains

Date: 12/3/18
Field Tests Against Adversaries

Computational Game Theory in the Field

Controlled

- 21 days of patrol, identical conditions
- Game theory vs Baseline+Expert

Not Controlled

Date: 12/3/18
New Directions in Stackelberg Security Games

- Threat Screening Games (AAAI16, IJCAI17, IJCAI18…)

- Cyber Security Games (IJCAI17, AAMAS18, CogSci18…)
Outline

Public Safety and Security
Stackelberg Security Games

Conservation/Wildlife Protection:
Green Security Games

Public Health/Social Work:
Influence maximization/Game against nature
Poaching of Wildlife in Uganda
Limited Intervention (Ranger) Resources to Protect Forests

Snare or Trap

Wire snares

Date: 12/3/18
Adversary not fully strategic; multiple “bounded rational” poachers

\[
\begin{align*}
\text{Max defender utility} & \quad \max_{x,q} \sum_{i \in X} \sum_{j \in Q} R_{ij} x_i q_j \\
\text{Defender mixed strategy} & \quad \text{s.t. } \sum_{i} x_i = 1 \\
& \quad 0 \leq (a - \sum_{i \in X} x_i) \leq (1 - q_j) M
\end{align*}
\]
Learn adversary bounded rational response: At each grid location $i$,

- **Ranger patrols:** $X(i)$
- **Features:** $F(i)$
- **Probability of finding snare in cell $i$:** $g_i$

Max defender utility

Max $x \sum_{i \in X} g_i(x_i)$

s.t. $\sum_i x_i = 1$

Defender mixed strategy
Learning Adversary Model
12 Years of Past Poaching Data

\[ g_j \]

- Probability of snare Per 1 KM Grid Square

Factors:
- Ranger patrol
- Animal density
- Distance to rivers / roads / villages
- Area habitat
- Area slope
- ...
Learning Adversary Model
Uncertainty in Observations

$$g_j$$

- Ranger patrol
- Animal density
- Distance to rivers / roads / villages
- Probability of snare Per 1 KM Grid Square
- Area habitat
- Area slope
- ...

Record: No Attack (NEG)

Record: Attack (POS)

Walk more!
Adversary Modeling
Imperfect Crime Observation-aware Ensemble Model

Training: Filtered Datasets

<table>
<thead>
<tr>
<th>Patrol Effort</th>
<th>Train Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image1" alt="Chart" /></td>
</tr>
<tr>
<td>1</td>
<td><img src="image2" alt="Chart" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image3" alt="Chart" /></td>
</tr>
</tbody>
</table>

Predict: Ensemble of Classifiers

- **Patrol Effort**
  - 0
  - 1
  - 2

- **Ensemble of Classifiers**
  - $C_0$
  - $C_1$
  - $C_2$
Poacher Attack Prediction in the Lab

Poacher Behavior Prediction

Results from 2016

- Train Labels
- SVM
- Bagging Ensemble
- Our Best Model

Date: 12/3/18
Real-world Deployment 2016: First Trial

- Two 9-sq. km patrol areas
  - Where there were infrequent patrols
  - Where no previous hot spots
Real-world Deployment
Two Hot Spots Predicted

- Poached Animals: Poached elephant
- Snaring: 1 elephant snare roll
- Snaring: 10 Antelope snares

<table>
<thead>
<tr>
<th>Historical Base Hit Rate</th>
<th>Our Hit Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average: 0.73</td>
<td>3</td>
</tr>
</tbody>
</table>

Date: 12/3/18
Model Predicted High Risk vs Low Risk Areas: 2 National Parks, 24 areas each, 6 months

Date: 12/3/18
Green Security Games: Incorporating Real Time Information

- Drones in Green Security Games (AAAI18, IAAI18, GameSec17…)

\[ \max_x \sum_{i \in X} g_i(x_i) \]
\[ s.t. \sum_i x_i = 1 \]
Green Security Games: Around the Globe with SMART partnership

600 National Parks Around the Globe

Wildlife, Forests, Fisheries…
Outline

Public Safety and Security
Stackelberg Security Games

Conservation/Wildlife Protection:
Green Security Games

Public Health:
Influence maximization/Game against nature

Date: 12/3/18

Prof Eric Rice
Social Work
Preventing HIV in homeless youth: Rates of HIV 10 times housed population

- **Shelters**: Limited number of peer leaders to spread HIV information in social networks
Influence Maximization Background

- **Given:**
  - Social network Graph G
  - Choose K “peer leader” nodes

- **Objective:**
  - Maximize expected number of influenced nodes

- **Assumption:** Independent cascade model of information spread
Independent Cascade Model and Real-world Physical Social Networks

\[ P(A, B) = 0.4 \]

\[ \mu = 0.5 \]

\[ \mu \in [0.3, 0.7] \]
Robust, Dynamic Influence Maximization

- Worst case parameters: a zero-sum game against nature

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>vs</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chooses policy, i.e., Chooses Peer leaders</td>
<td></td>
<td>Chooses parameters $\mu, \sigma$</td>
</tr>
</tbody>
</table>

- Payoffs: (performance of algorithm)/OPT
HEALER Algorithm [2017]
Robust, Dynamic Influence Maximization

*Theorem:* Converge with approximation guarantees

- Equilibrium strategy despite exponential strategy spaces: Double oracle

<table>
<thead>
<tr>
<th></th>
<th>Nature</th>
<th>Nature’s oracle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Params #1</td>
<td>Params #2</td>
</tr>
<tr>
<td>Policy #1</td>
<td>0.8, -0.8</td>
<td>0.3, -0.3</td>
</tr>
<tr>
<td>Policy #2</td>
<td>0.7, -0.7</td>
<td>0.5, -0.5</td>
</tr>
<tr>
<td>Policy #3</td>
<td>0.6, -0.6</td>
<td>0.4, -0.4</td>
</tr>
</tbody>
</table>

Wilder

Theorem: Converge with approximation guarantees
Challenge: Multi-step Policy

<table>
<thead>
<tr>
<th></th>
<th>Params #1</th>
<th>Params #2</th>
<th>Params #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy #1</td>
<td>0.8, -0.8</td>
<td>0.3, -0.3</td>
<td>0.4, -0.4</td>
</tr>
<tr>
<td>Policy #2</td>
<td>0.7, -0.7</td>
<td>0.5, -0.5</td>
<td>0.6, -0.6</td>
</tr>
<tr>
<td>Policy #3</td>
<td>0.6, -0.6</td>
<td>0.4, -0.4</td>
<td>0.7, -0.7</td>
</tr>
</tbody>
</table>

K = 4
1\text{st} time step

K = 4
2\text{nd} time step

Date: 12/3/18
HEALER: POMDP Model for Multi-Step Policy [2015]
Robust, Dynamic Influence Maximization

<table>
<thead>
<tr>
<th>Params #1</th>
<th>Params #2</th>
<th>Params #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy #1</td>
<td>0.8, -0.8</td>
<td>0.3, -0.3</td>
</tr>
<tr>
<td>Policy #2</td>
<td>0.7, -0.7</td>
<td>0.5, -0.5</td>
</tr>
<tr>
<td>Policy #3</td>
<td>0.6, -0.6</td>
<td>0.4, -0.4</td>
</tr>
</tbody>
</table>

Choose nodes

Observation: Update propagation probability

POMDP partitions
Pilot Tests with HEALER with 170 Homeless Youth [2017]

Recruited youths:

<table>
<thead>
<tr>
<th>HEALER</th>
<th>HEALER++</th>
<th>DEGREE CENTRALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>56</td>
<td>55</td>
</tr>
</tbody>
</table>

12 peer leaders
Results: Pilot Studies

Percent of non-Peer Leaders

- **HEALER**
  - Informed: 70%
  - Not Informed: 30%

- **HEALER++**
  - Informed: 65%
  - Not Informed: 35%

- **Degree**
  - Informed: 60%
  - Not Informed: 40%

Informed Non-Peer Leaders Who Started Testing for HIV

- **HEALER**
  - Testing: 30%
  - Non-Testing: 70%

- **HEALER++**
  - Testing: 25%
  - Non-Testing: 75%

- **Degree**
  - Testing: 20%
  - Non-Testing: 80%

Date: 12/3/18
New Directions: Los Angeles
From an Angeleno

900 youth study

(AAAI18, AAMAS18)

Mayor Garcetti @ USC

HELP
New Directions: Mumbai
From a Mumbaikar

Prime Minister Modi @ Mumbai
AI for Social Good

Date: 12/3/18
Key Lessons: Directing Multiagent Systems Research towards Social Good

Multiagent systems research helps address complex social problems:
- Public safety & security, conservation, public health

Shared multiagent research challenges, solutions across problem areas:
- **Challenge**: Optimize limited intervention resources in interacting with others
- **Solution**: Computational game theory models/algorithms
- **New models**: Stackelberg security games, green security games...
- **Key algorithms**: Incremental strategy generation, marginals, double oracle...

Immersion/Deployment helps identify crucial research challenges
Future: Multiagent Systems and AI Research for Social Good

Tremendous potential: Improving society & fighting social injustice

Vital to bring AI to those not benefiting from AI, e.g., global south

Embrace interdisciplinary research -- social work, conservation
When working on AI for Societal Benefits:

- **Important step out of lab & into the field**
- **Societal impact**
- **Actual problem for societal benefit?**
- **Model deficiencies for new research directions?**