AI for Social Impact: Learning & Planning in the Data to Deployment Pipeline

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Harvard University
&
Director “AI for Social Good”
Google Research India
AI for Social Impact

Public Safety and Security
Conservation
Public Health
Viewing Social Problems as Multiagent Systems

Key research challenge across problem areas:

Optimize Our Limited Intervention Resources

Use of multiagent Systems Reasoning:
Game Theory, Networks

Overview of 14 years of work
Public Safety and Security
Optimizing Limited Intervention (Security) Resources

Counter-Terrorism: Protecting Airports, Ports, Trains

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

Protecting Endangered Wildlife, Forests, Fisheries

- Security games and adversary (poacher) behavior prediction
- Real-world: National parks in Uganda, Malaysia…
HIV Prevention, TB Prevention, Suicide Prevention

- Social networks to enhance intervention, e.g., HIV information
- Real-world pilot tests: Homeless youth shelters in Los Angeles
Director, AI for Social Good

Google Research Bangalore (Forthcoming)
Optimizing Limited Intervention Resources

- New projects in public health, conservation, education

Workshop on AI for Social Good
November 4-5, 2019
Google Bangalore

Public Health & Welfare
Conservation
Education

Date: 5/30/2020
Common Themes
Interdisciplinary Partnerships, Multiagent Systems, Data-to-deployment pipeline
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Interdisciplinary Partnerships, Multiagent Systems, Data-to-deployment pipeline

- Immersion
  - Data Collection
- Predictive model
  - Learning/Expert input
- Prescriptive algorithm
  - Multiagent Reasoning; Intervention
- Field tests & deployment

Date: 5/30/2020
**AI for Social Impact**

**Observations on Area of Research**

*Field tests & deployments because Social Impact is a key objective!*

*Encourage AI for Social Impact research: Value entire pipeline (contributions beyond algorithms in data collection, model, impact)*

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**Diagram:**

1. **Immersion**
   - Data Collection

2. **Predictive model**
   - Learning/Expert input

3. **Prescriptive algorithm**
   - Game theory Intervention

4. **Field tests & deployment**
Outline: Overview of Past 14 Years of Research

Public Safety & Security: Stackelberg Security Games

Conservation/Wildlife Protection: Green Security Games

Public Health: Influence maximization/Game against nature

- Real world evaluation
- PhD students & postdocs
Game Theory direct use for security resource optimization?

Erroll Southers

LAX Airport, Los Angeles

Glasgow: June 30, 2007

Date: 5/30/2020
Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

<table>
<thead>
<tr>
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<th>Terminal #1</th>
<th>Terminal #2</th>
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Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

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Adversary

Defender

Date: 5/30/2020
Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

**Key idea**: Intelligent randomization, more frequently visit some targets

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

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<td>2, -1</td>
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Date: 5/30/2020
## ARMOR at LAX
Basic Security Game Operation [2007]

<table>
<thead>
<tr>
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<th>Target #1</th>
<th>Target #2</th>
<th>Target #3</th>
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<tr>
<td>Defender #3</td>
<td></td>
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**AI (GAME THEORY REASONING) PROGRAM**

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

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### 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>
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</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></td>
<td>Team4</td>
</tr>
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<td>...</td>
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</tbody>
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Date: 5/30/2020
First application: Computational game theory for operational security

January 2009

- January 3rd: Loaded 9/mm pistol
- January 9th: 16-handguns, 1000 rounds of ammo
- January 10th: Two unloaded shotguns
- January 12th: Loaded 22/cal rifle
- January 17th: Loaded 9/mm pistol
- January 22nd: Unloaded 9/mm pistol
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….
1000 flights, 20 air marshals: $10^{41}$ combinations

<table>
<thead>
<tr>
<th></th>
<th>Attack 1</th>
<th>Attack 2</th>
<th>Attack ...</th>
<th>Attack 1000</th>
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<tbody>
<tr>
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<td>4,-8</td>
<td>...</td>
<td>-20,9</td>
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<tr>
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<td>4,-8</td>
<td>...</td>
<td>-20,9</td>
</tr>
<tr>
<td>1, 3, 5 ..</td>
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</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>$10^{41}$ rows</td>
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</table>
PROTECT: Port and Ferry Protection Patrols [2011] Using Marginals for Scale up

Boston  Los Angeles  New York

Meritorious Team Commendation from Commandant (US Coast Guard)

Date: 5/30/2020
Solving Problems: Overall Research Framework
End-to-End, Data to Deployment Pipeline

- Immersion
  - Data Collection

- Predictive model
  - Learning/Expert input

- Prescriptive algorithm
  - Game theory Intervention

- Field tests & deployment
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: 5/30/2020
Poaching of Wildlife in Uganda
Limited Intervention (Ranger) Resources to Protect Forests

Snare or Trap

Wire snares
Repeated attacks by multiple poachers
Learn adversary response: At each grid location $i$

- Ranger patrols: $X(i)$
- Features: $F(i)$

Probability of finding snare in cell $i$
Ensemble Approach for Learning Adversary Model
12 Years of Past Poaching Data

- Ranger patrol
- Animal density
- Distance to rivers / roads / villages
- Probability of snare Per 1 KM Grid Square
- Area habitat
- Area slope
- ...
PAWS: Real-world Deployment 2016: First Trial

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

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

Historical Base Hit Rate | Our Hit Rate
--- | ---
Average: 0.73 | 3

Date: 5/30/2020
PAWS Predicted High vs Low Risk Areas: 2 National Parks, 24 areas each, 6 months [2017]

Snares per patrolled sq. KM

<table>
<thead>
<tr>
<th>Experiment group</th>
<th>High-risk</th>
<th>Low-risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25</td>
<td></td>
</tr>
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</tbody>
</table>

Snares per patrolled sq. KM

<table>
<thead>
<tr>
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<th>Low-risk</th>
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<tbody>
<tr>
<td></td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.4</td>
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</tr>
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<td></td>
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Date: 5/30/2020
PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary [2018-2019]

Srepok Wildlife Sanctuary has been identified as the most suitable site for tiger reintroduction in Southeast Asia.
PAWS Real-world Deployment
Trials in Cambodia: Srepok National Park [2018-2019]

“@Milind: I am Super excited with the results. Let’s get this going on other countries too this year.”

Rohit Singh, WWF (2019)

Snares per patrolled sq. KM

- High-risk
- Medium-risk
- Low-risk

<table>
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<th>Medium-risk</th>
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</thead>
<tbody>
<tr>
<td>2018</td>
<td>521snares/month</td>
<td>101snares/month</td>
</tr>
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</table>
Green Security Games: Around the Globe with SMART partnership [2019]

Protect Wildlife
800 National Parks Around the Globe

Also: Protect Forests, Fisheries…
Green Security Games: Integrating Real-Time Information in the Pipeline

Learn predictions with Historical Ground Truth Data

Data Collection

Prediction

Prescription

Field

Date: 5/30/2020
Green Security Games: Integrating Real-Time “SPOT” Information [2018]

Goal: automatically find poachers
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
- “Real” social networks gathered from observations in the field; not facebook etc
HEALER Algorithm: Influence Maximization

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

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

- **Assumption:** Independent cascade model of information spread
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 [2017]

Percent of non-Peer Leaders

- Informed
- Not Informed

Informed Non-Peer Leaders Who Started Testing for HIV

- Testing
- Non-Testing

Date: 5/30/2020
AI Assistant: HEALER
Continuing Research on HIV prevention [2019]

- Completing 900 youth study at three homeless shelters
Tuberculosis (TB): ~500,000 deaths/year, ~3M infected in India

- Patient in low resource communities: Non-adherence to TB Treatment
- Digital adherence tracking: Patients call phone #s on pill packs; many countries
- Predict adherence risk from phone call patterns? Intervene before patients miss dose
TB Treatment Adherence but Limited Resources: Intervening Selectively before patients miss doses

- **Data Collect**
  - Phone logs

- **Predict high risk patients**
  - RF or LSTM

- **Prescription Constraint Top K**

- **Field**

- 15K patients, 1.5M calls

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Date: 5/30/2020
Increasing TB Treatment Adherence: Intervening before patients miss doses [2019]

Data from State of Maharashtra India

Best Model vs. Baseline: Prediction High Risk Patients

- True Positives: Baseline 107 vs. Best Model 144 (+35%)
- False Positives: Baseline 120 vs. Best Model 97 (-19%)

Date: 5/30/2020
Integrating with Everwell’s Platform

This work has a lot of potential to save lives.

Bill Thies
Co-founder, Everwell Health Solutions
Summary
AI & Multiagent Systems for Social Impact

Cross-cutting challenge: How to optimize limited intervention resources
- Public safety & security, conservation, public health

Unifying themes
- Multiagent systems reasoning
- Data to deployment
Future: Multiagent Systems and AI Research for Social Good

- It is possible to simultaneously advance AI research & do social good
- Data to deployment perspective: Not just improving algorithms
- Important to step out of the lab and into the field
- Embrace interdisciplinary research -- social work, conservation
- Lack of data is the norm, a feature; part of the project strategy
- AI for Social Impact should be evaluated differently
Thank you!

AI has tremendous potential to
Improving society & fighting social injustice

@MilindTambe_AI