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

MILIND TAMBE

Director Center for Research on Computation and Society

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



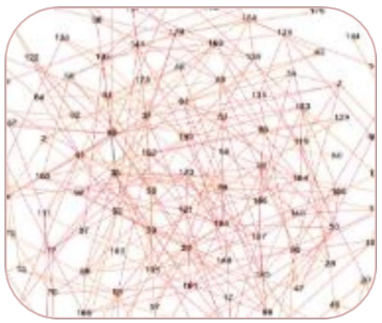


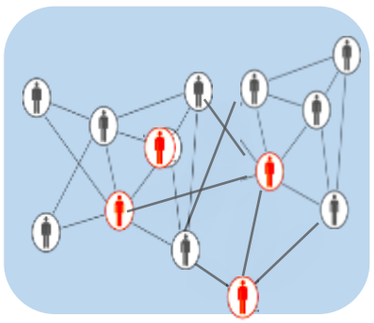


- Security games and adversary (poacher) behavior prediction
- Real-world: National parks in Uganda, Malaysia…

Public Health
Optimizing Limited Intervention (Health Worker) Resources

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

Google Research Bangalore (Forthcoming)
Optimizing Limited Intervention Resources

Director, AI for Social Good

Public Health & Welfare

Conservation

Education

- New projects in public health, conservation, education

Common Themes

Interdisciplinary Partnerships, Multiagent Systems, Data-to-deployment pipeline

Wildlife Conservation Society

WWF

United States Coast Guard
U.S. Department of Homeland Security

Transportation Security Administration

LOS ANGELES LGBT CENTER

S.P.Y
safe place for youth

my friend's place

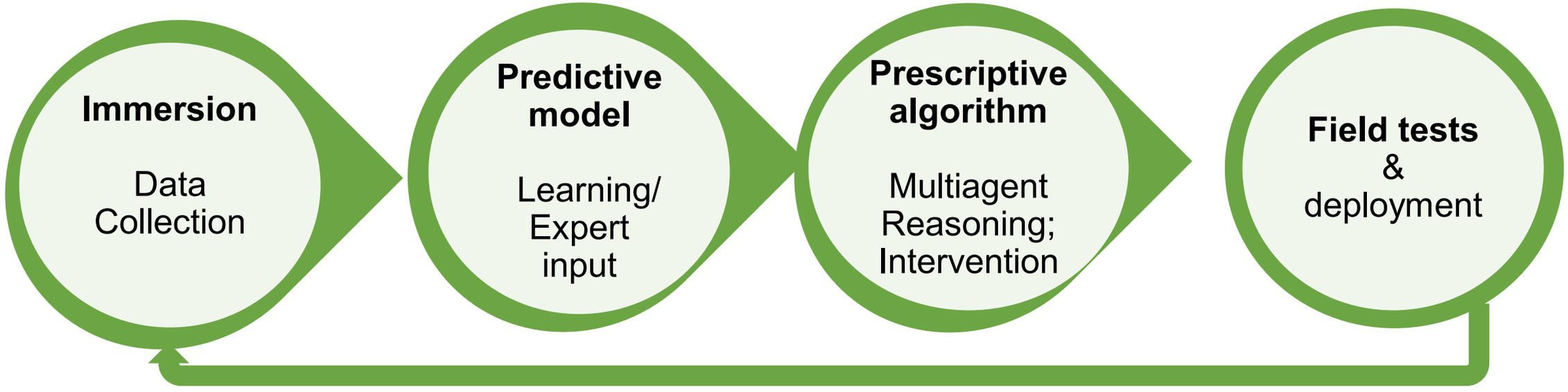
everwell

SMART

Air Shepherd
The Lindbergh Foundation

Common Themes

Interdisciplinary Partnerships, Multiagent Systems, Data-to-deployment pipeline



Wildlife Conservation Society

WWF

United States Coast Guard
U.S. Department of Homeland Security

Transportation Security Administration

LOS ANGELES LGBT CENTER

S.P.Y
safe place for youth

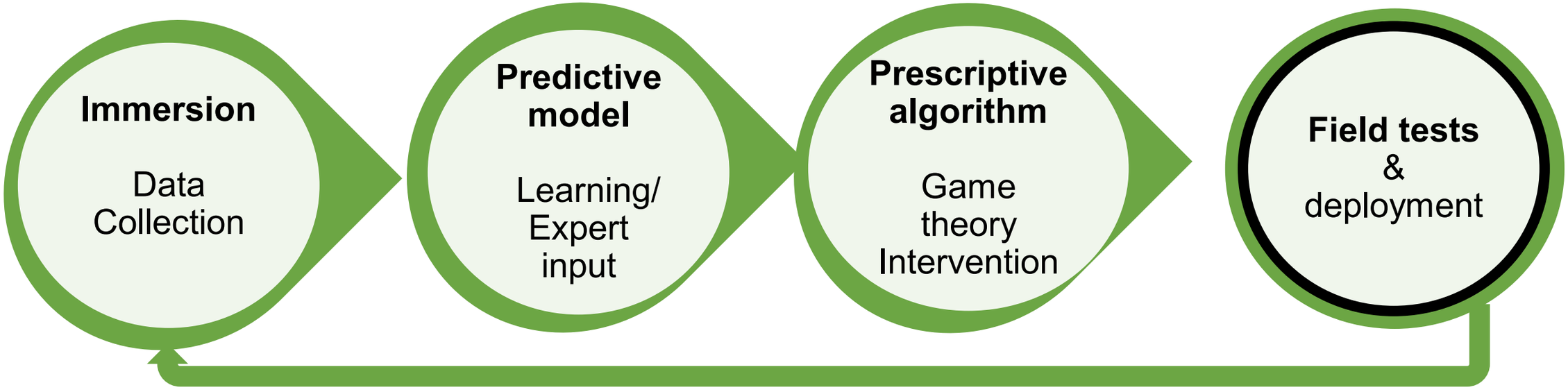
my friend's place

everwell

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)



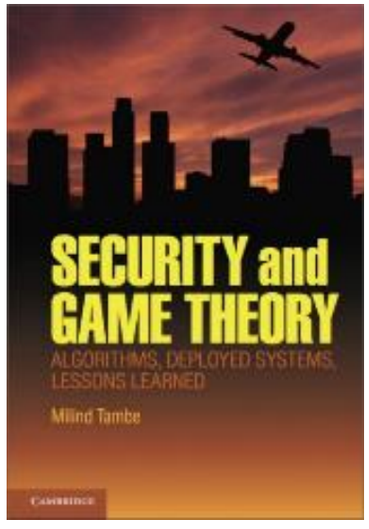
Outline: Overview of Past 14 Years of Research

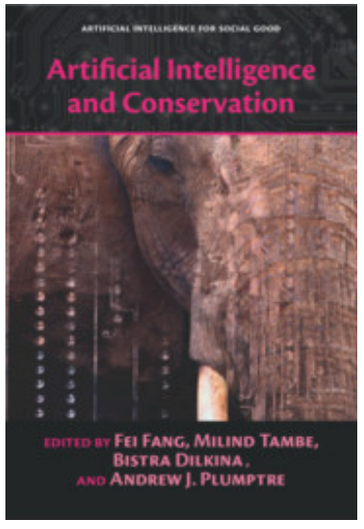
Public Safety & Security: Stackelberg Security Games

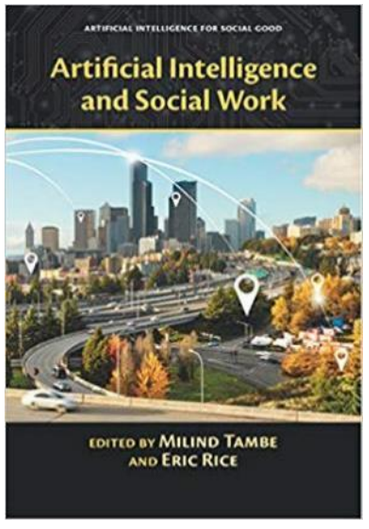
Conservation/Wildlife Protection: Green Security Games

Public Health: Influence maximization/Game against nature

- Real world evaluation
- PhD students & postdocs



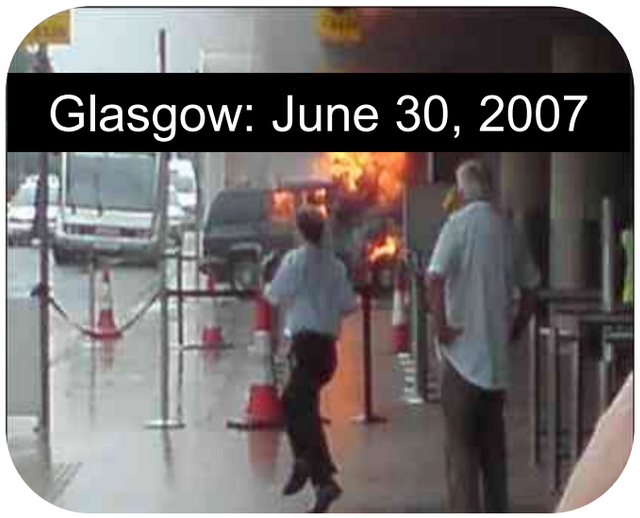




ARMOR Airport Security: LAX(2007)
Game Theory direct use for security resource optimization?

Erroll Southers

LAX Airport, Los Angeles



Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	-1, 1
Terminal #2	-5, 5	2, -1

Game Theory for Security Resource Optimization

New Model: Stackelberg Security Games

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	-1, 1
Terminal #2	-5, 5	2, -1

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

Adversary

Defender

	Terminal #1	Terminal #2
Terminal #1	4, -3	-1, 1
Terminal #2	-5, 5	2, -1

ARMOR at LAX
Basic Security Game Operation [2007]


Kiekintveld


Pita

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

AI (GAME THEORY REASONING) PROGRAM

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

Canine Team Schedule, July 28								
	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
8 AM		Team1			Team3	Team5		
9 AM			Team1	Team2				Team4
…	…	…	…	…	…	…	…	…

ARMOR:
Optimizing Security Resource Allocation [2007]

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

Newsweek

ARMOR…throws a digital cloak of invisibility….

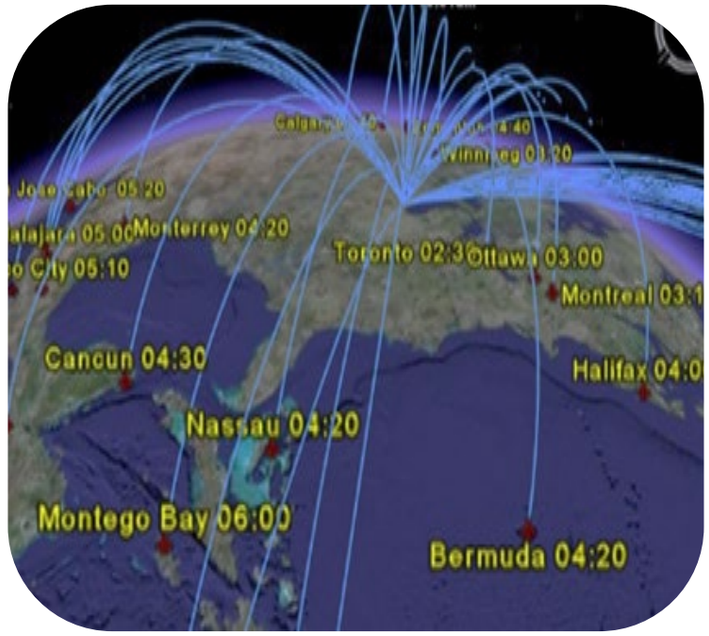
IRIS
Federal Air Marshals Service [2009]


Kiekintveld


Jain

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

	Attack 1	Attack 2	Attack …	Attack 1000
1, 2, 3 ..	5,-10	4,-8	…	-20,9
1, 2, 4 ..	5,-10	4,-8	…	-20,9
1, 3, 5 ..	5,-10	-9,5	…	-20,9
…	← 10^{41} rows			



PROTECT: Port and Ferry Protection Patrols [2011]
Using Marginals for Scale up

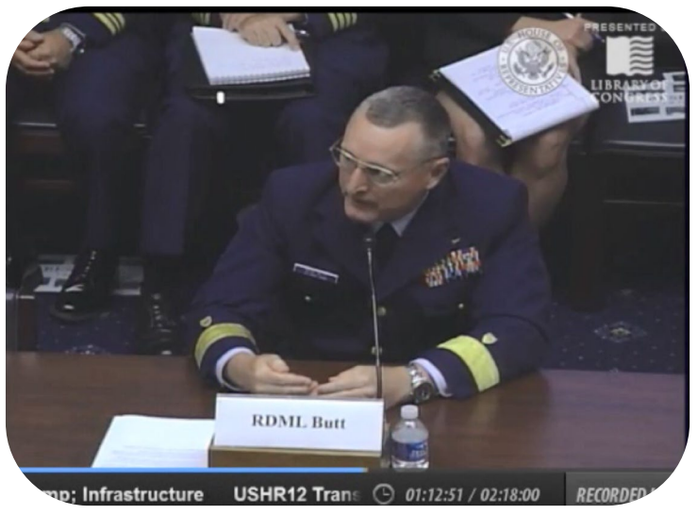

Shieh


An

Boston

Los Angeles

New York



Meritorious Team Commendation from Commandant (US Coast Guard)

Solving Problems: Overall Research Framework
End-to-End, Data to Deployment Pipeline

Immersion

Data Collection

Predictive model

Learning/ Expert input

Prescriptive algorithm

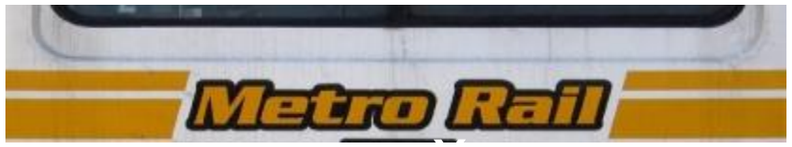
Game theory Intervention

Field tests & deployment

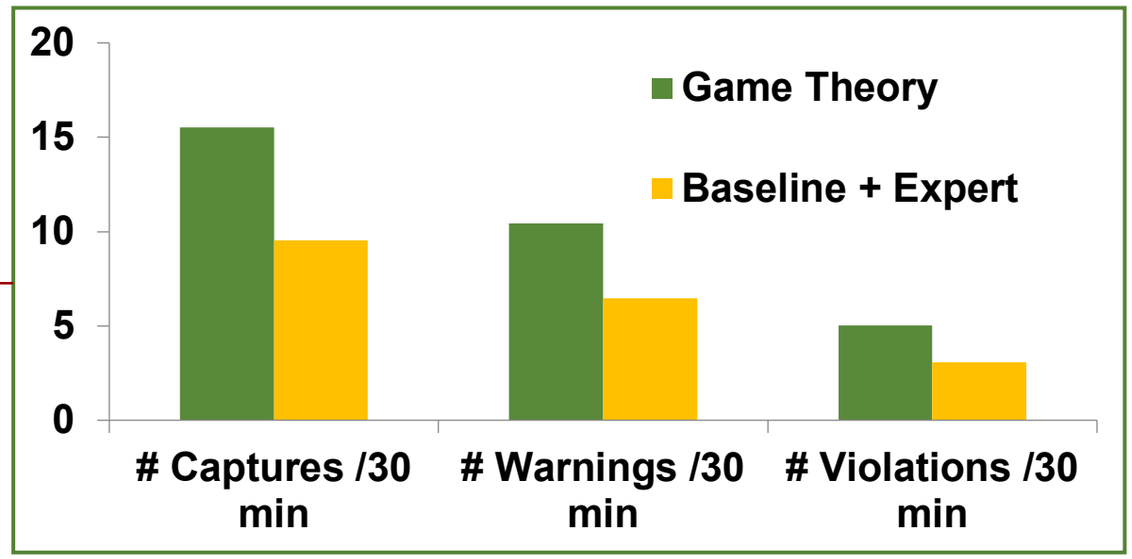
Field Tests Against Adversaries

Computational Game Theory in the Field

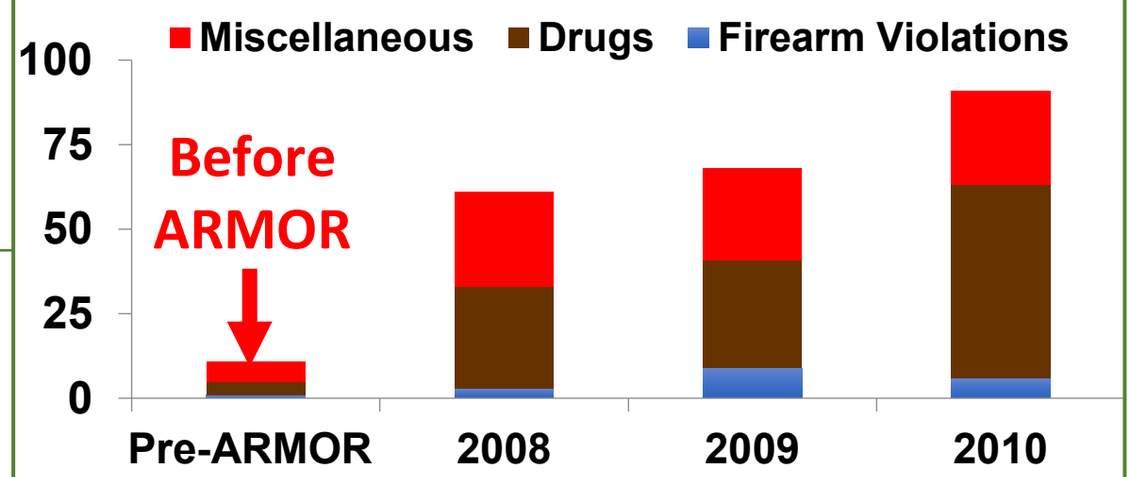
Controlled



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



Not Controlled



Outline

Public Safety & Security: Stackelberg Security Games

Conservation/Wildlife Protection: Green Security Games

Dr Andy Plumptre
Conservation Biology

Public Health: Influence maximization/Game against nature

Poaching of Wildlife in Uganda
Limited Intervention (Ranger) Resources to Protect Forests

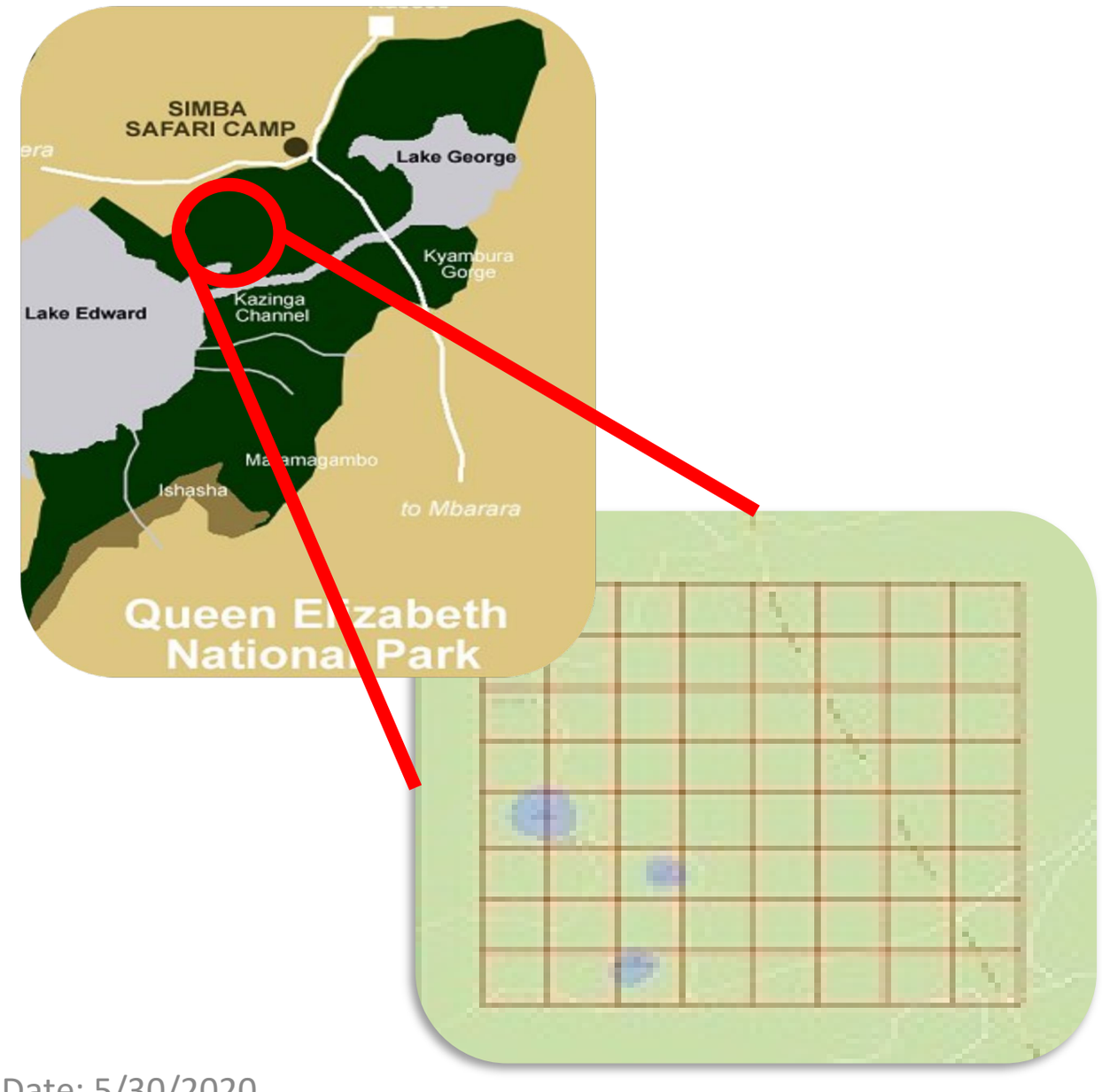
Snare or Trap

Wire snares

Green Security Games[2015]
Limited Ranger Resources to Protect Forests

Fang

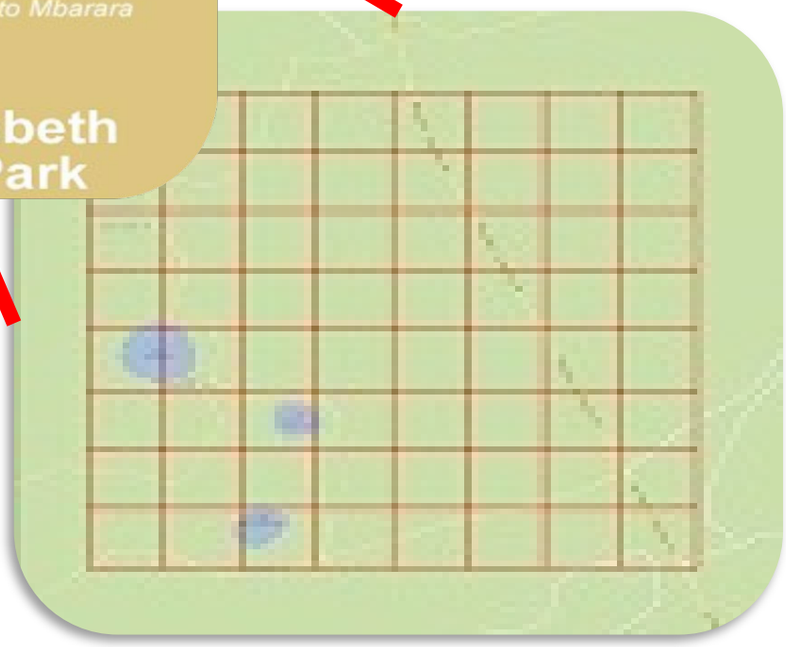
Repeated attacks by multiple poachers



Green Security Games [2015]
Game Theory + Machine Learning Poacher Behavior

Xu

Learn adversary response: At each grid **location i**



Ranger patrols: $X_{(i)}$

Features: $F_{(i)}$

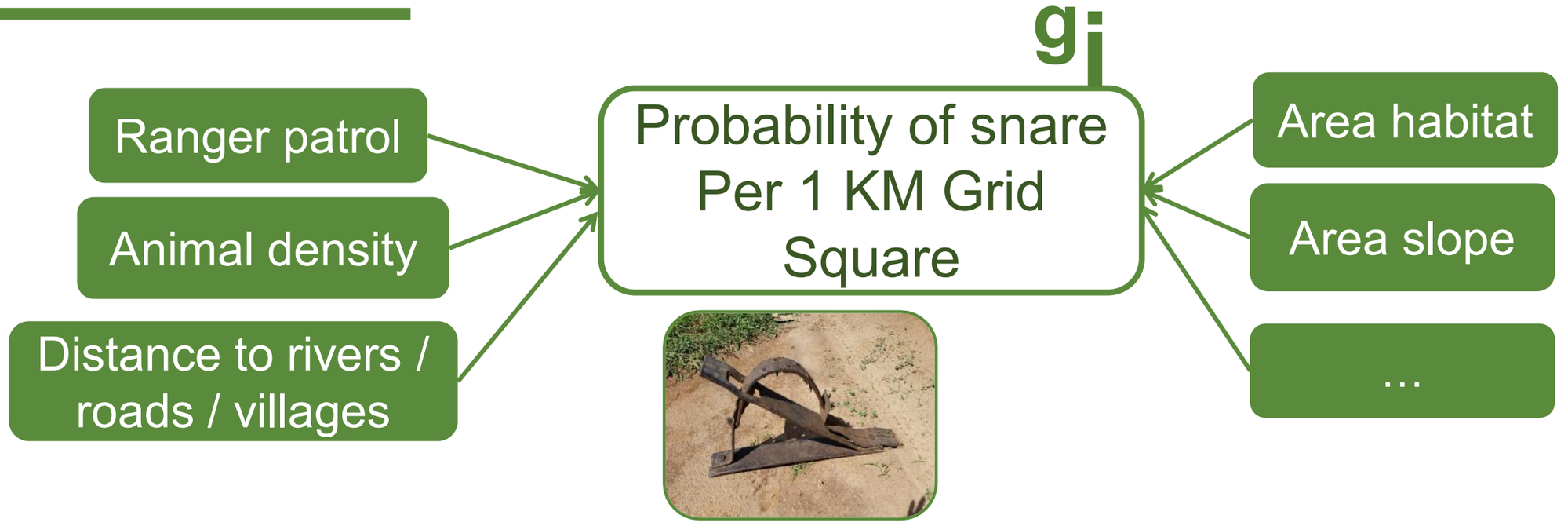
Machine Learning

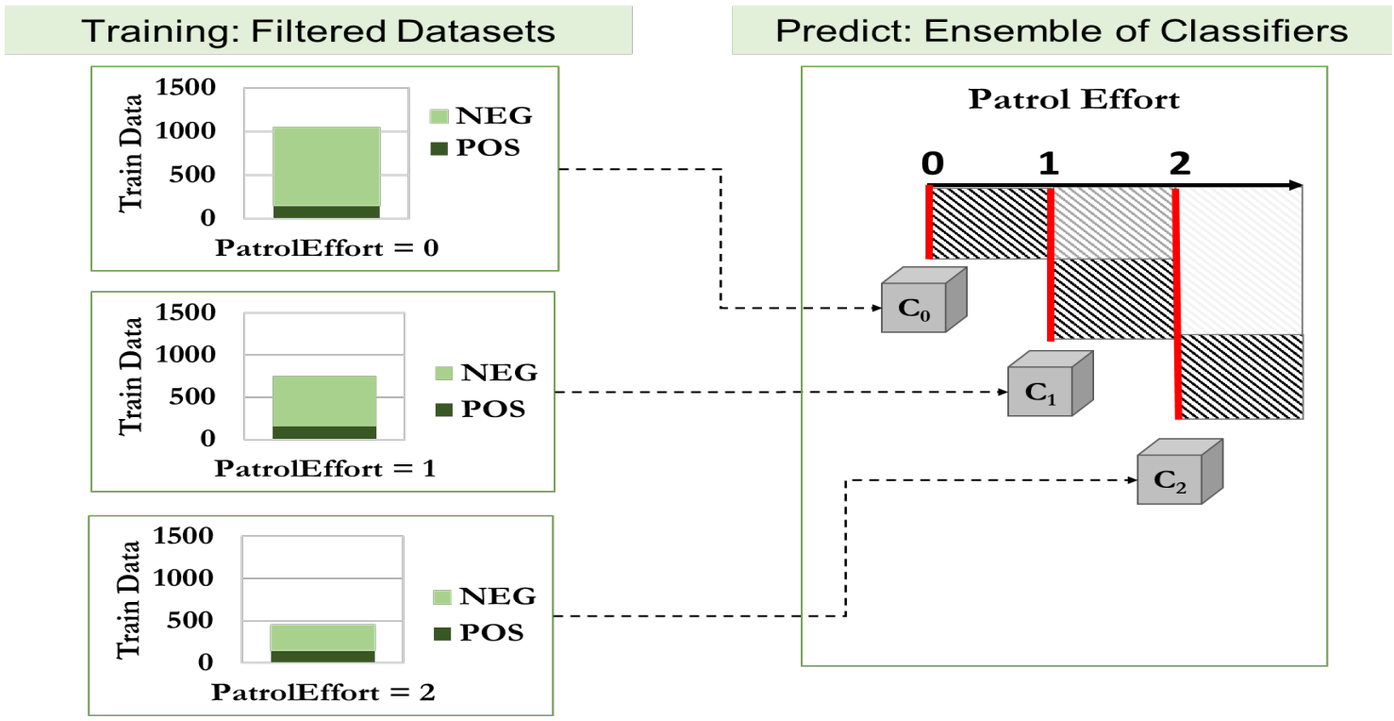
g_i

Probability of finding snare in cell i

Ensemble Approach for Learning Adversary Model 12 Years of Past Poaching Data

Nguyen



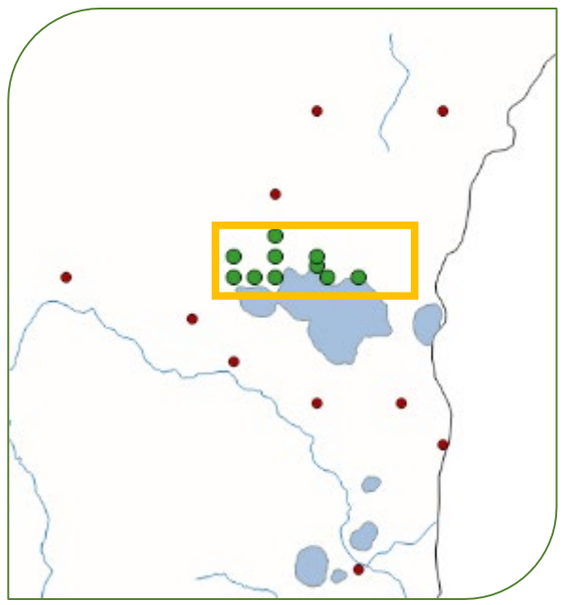


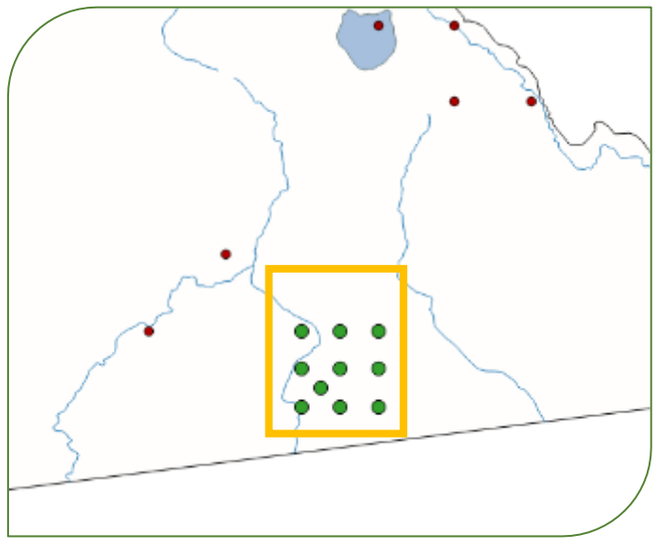
PAWS:
Real-world Deployment 2016: First Trial

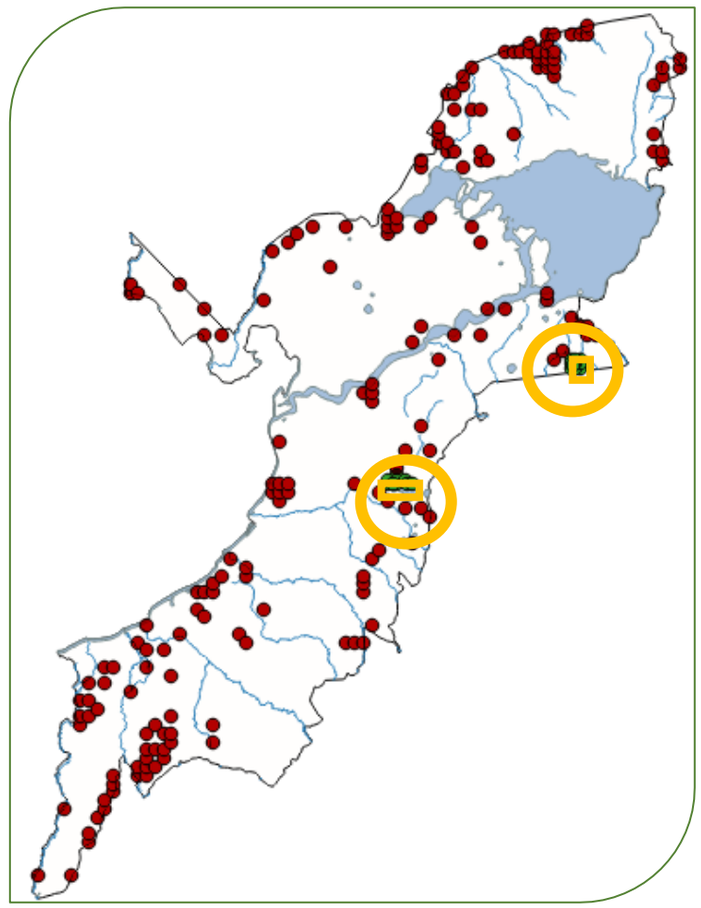

Ford


Gholami

- Two 9-sq. km patrol areas
  - Where there were infrequent patrols
  - Where no previous hot spots







PAWS Real-world Deployment
Two Hot Spots Predicted


Ford

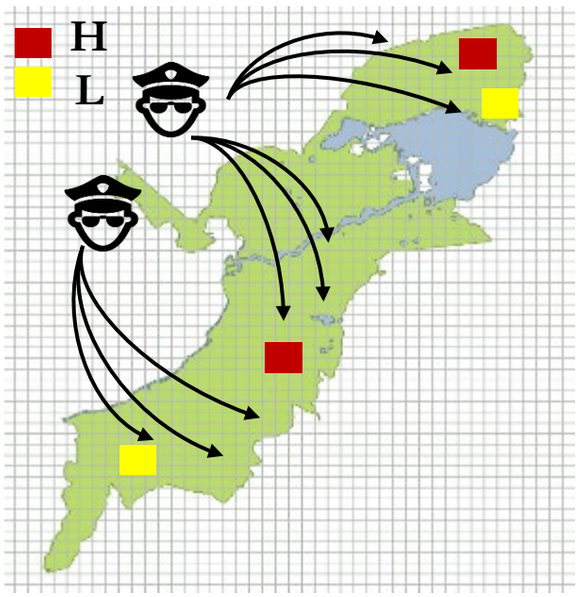

Gholami

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

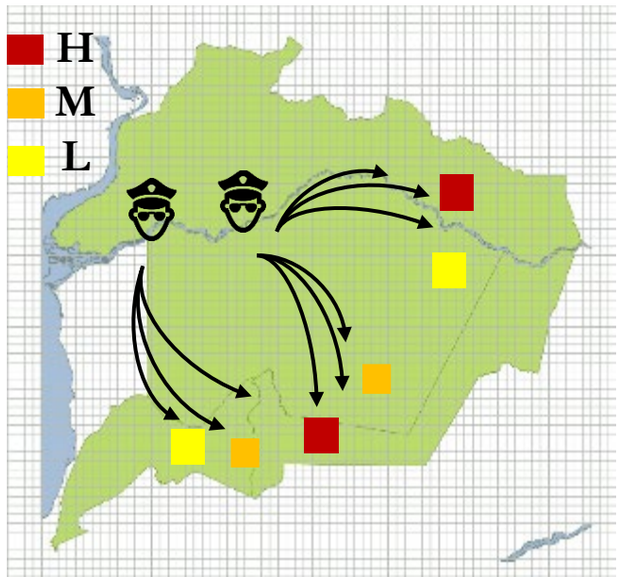
Historical Base Hit Rate	Our Hit Rate
Average: 0.73	3

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

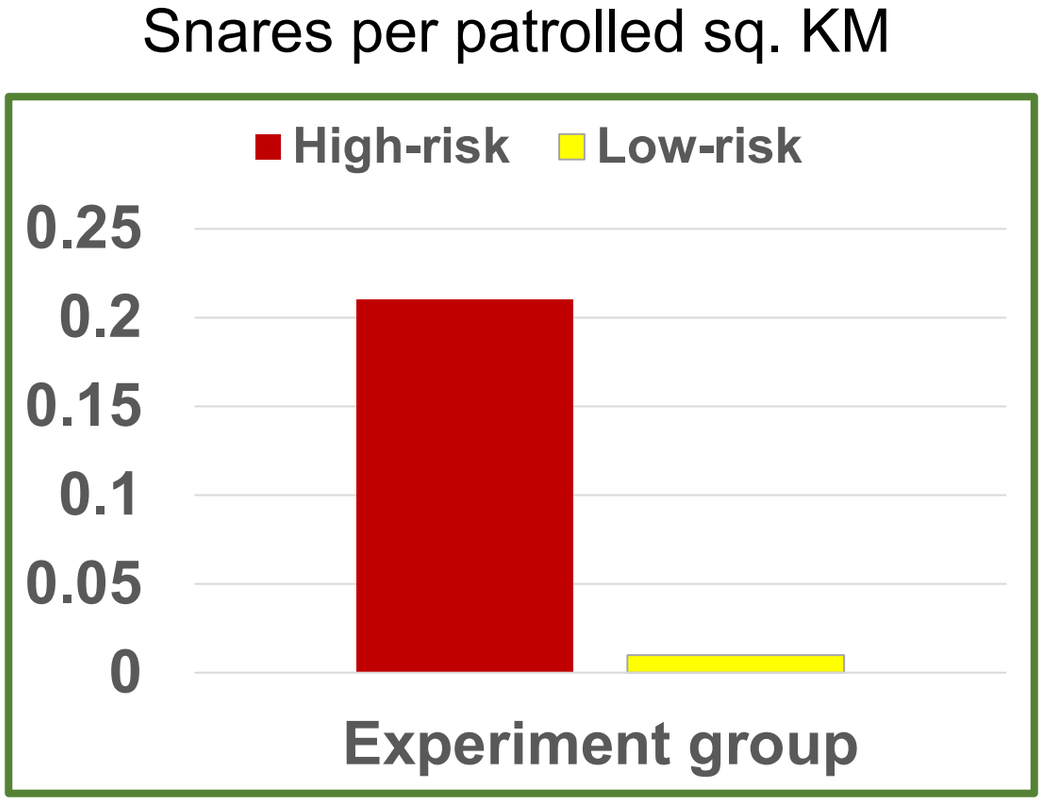

Gholami

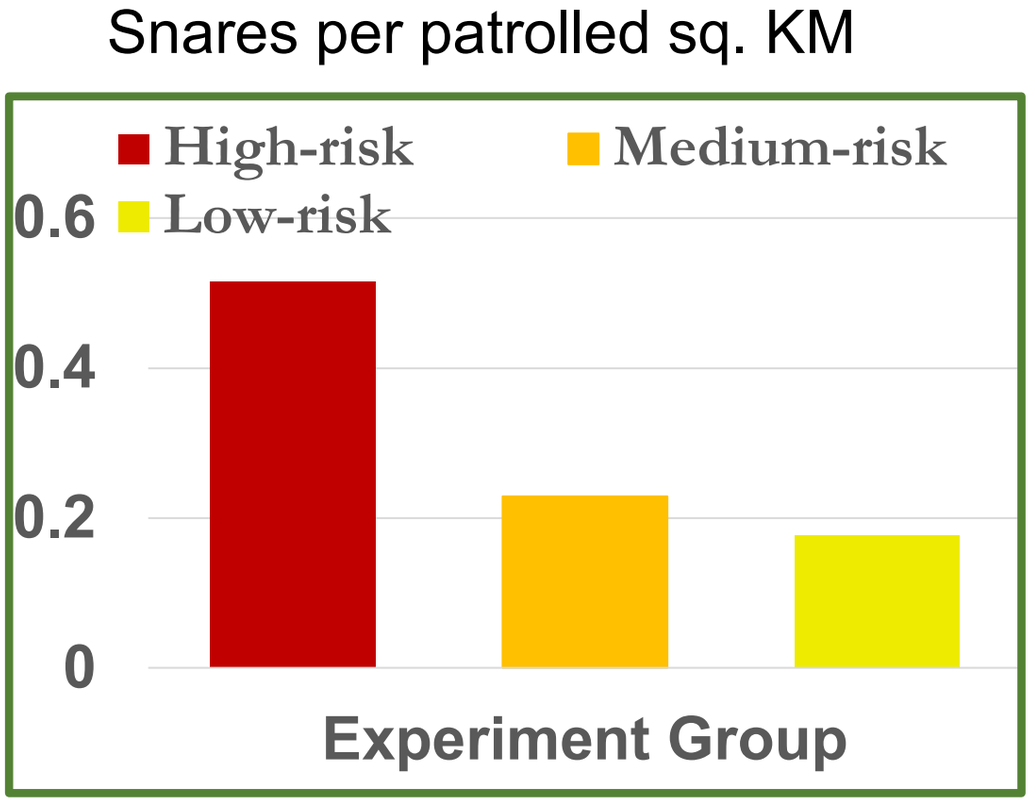


Queen Elizabeth National Park



Murchison Falls National Park



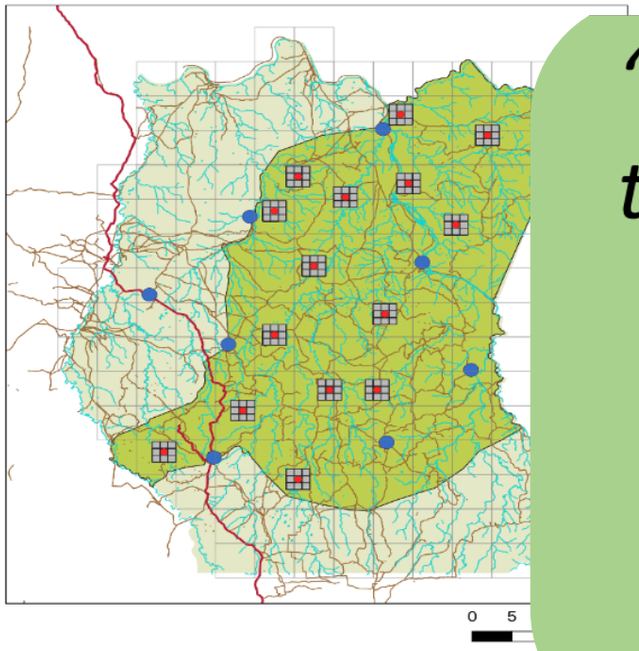


PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary [2018-2019]


Xu

PAWS Real-world Deployment
Trials in Cambodia: Srepok National Park [2018-2019]

Xu



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

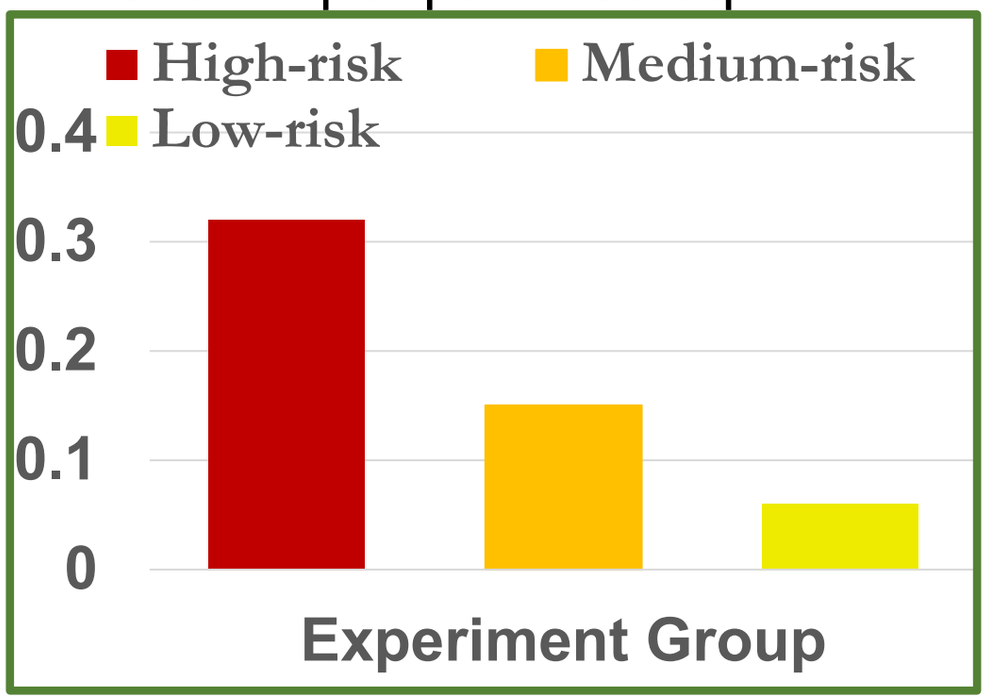
Rohit Singh, WWF (2019)

- *521 snares/month our tests*

vs

- *101 snares/month 2018*

Snares per patrolled sq. KM

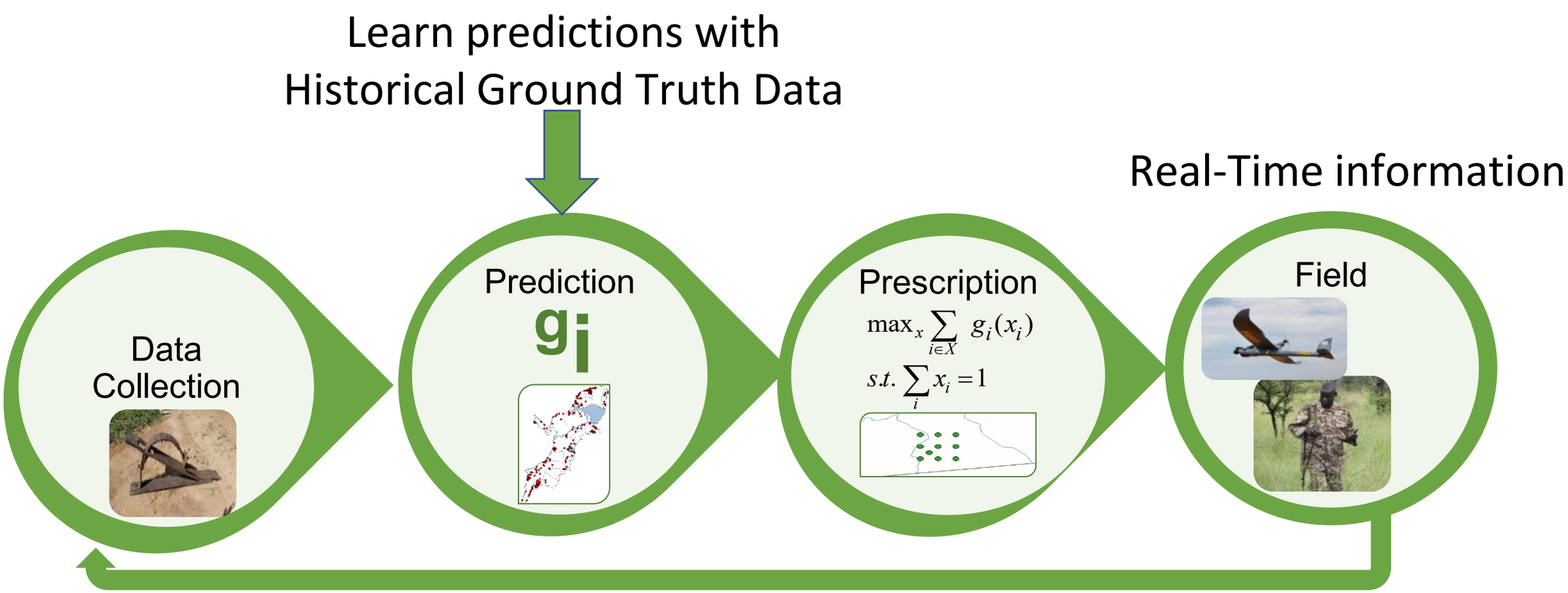


Green Security Games:
Around the Globe with SMART partnership [2019]

Protect Wildlife
800
National Parks
Around the Globe

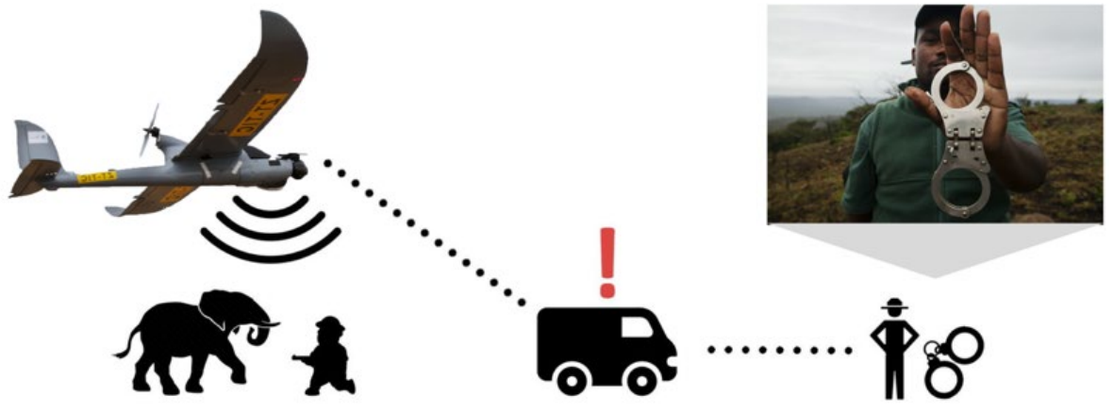
Also: Protect Forests, Fisheries…

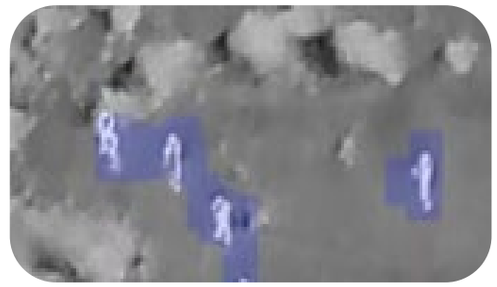
Green Security Games:
Integrating Real-Time Information in the Pipeline

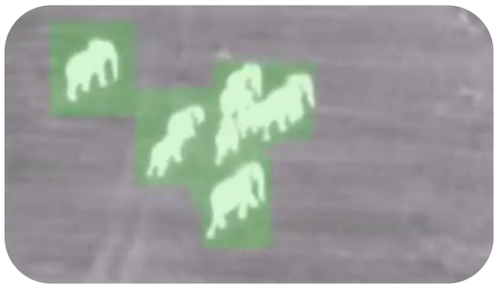


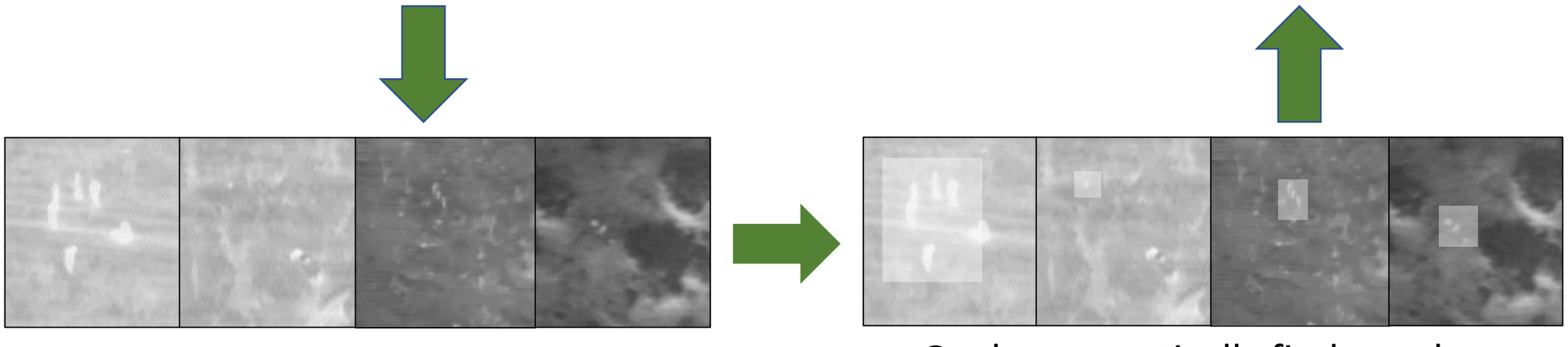
Green Security Games: Integrating Real-Time "SPOT" Information [2018]

Bondi









Goal: automatically find poachers

Outline

Public Safety & Security: Stackelberg Security Games

Conservation/Wildlife Protection: Green Security Games

Public Health: Game against nature

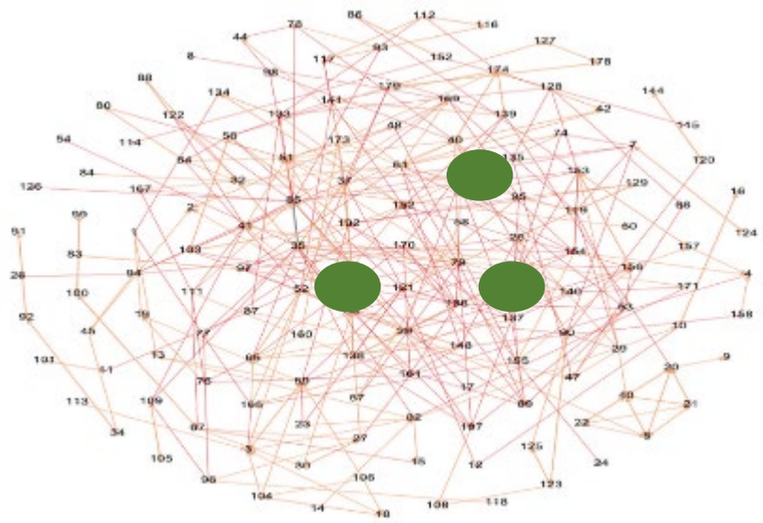
Prof Eric Rice
Social Work

Public Health
Optimizing Limited Intervention (Social Worker) Resources

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]


Yadav


Wilder

Recruited youths:

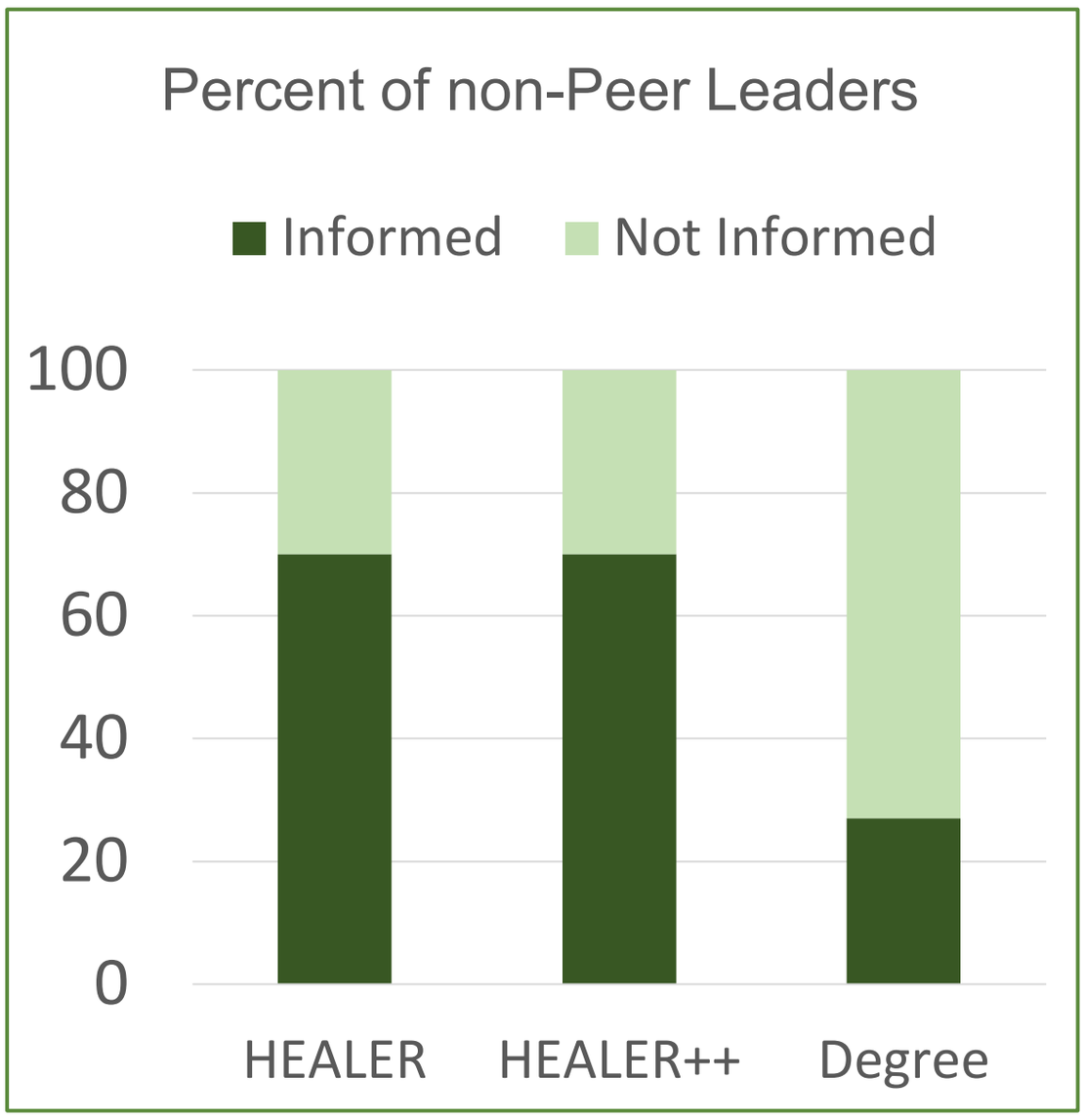
HEALER	HEALER++	DEGREE CENTRALITY
62	56	55

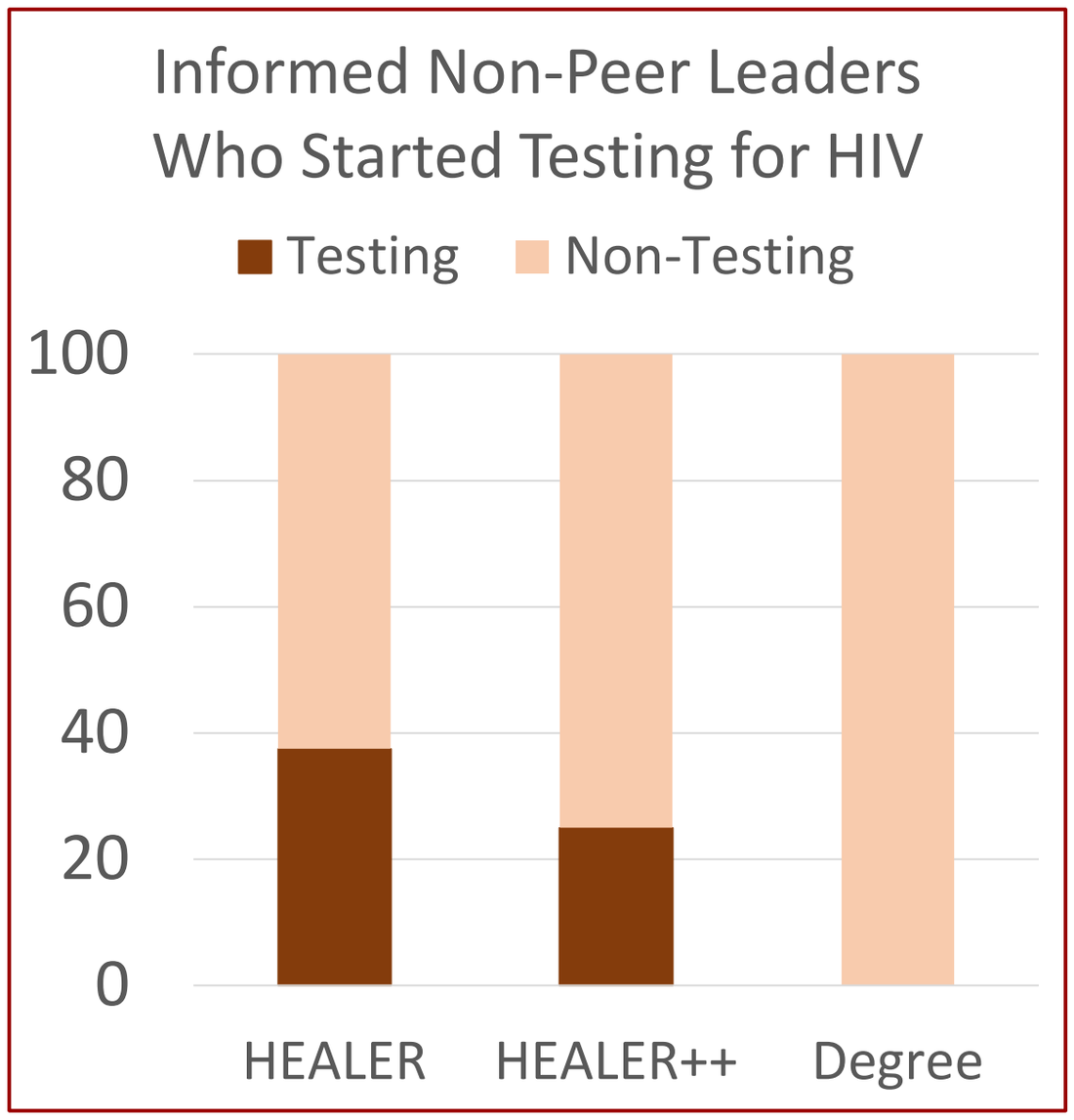
12 peer leaders

Results: Pilot Studies [2017]


Yadav


Wilder





AI Assistant: HEALER

Continuing Research on HIV prevention [2019]

- Completing 900 youth study at three homeless shelters

my friend's place

S.P.Y

safe place for youth

LOS ANGELES LGBT CENTER

Public Health: Optimizing Limited Social Worker Resources Preventing Tuberculosis in India [2019]

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

Killian

Data Collect

Phone logs

Predict high risk patients

RF or LSTM

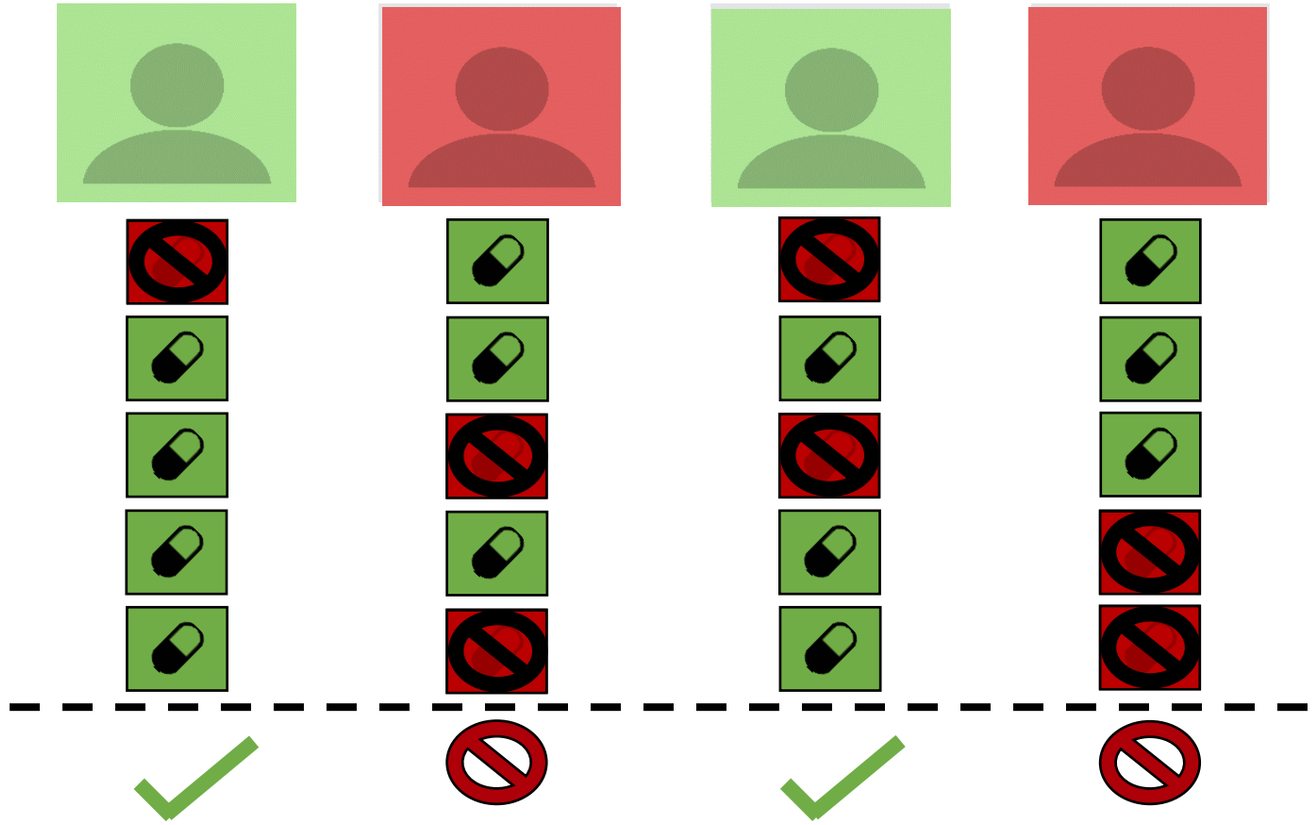
Prescription

Constraint Top K

Field

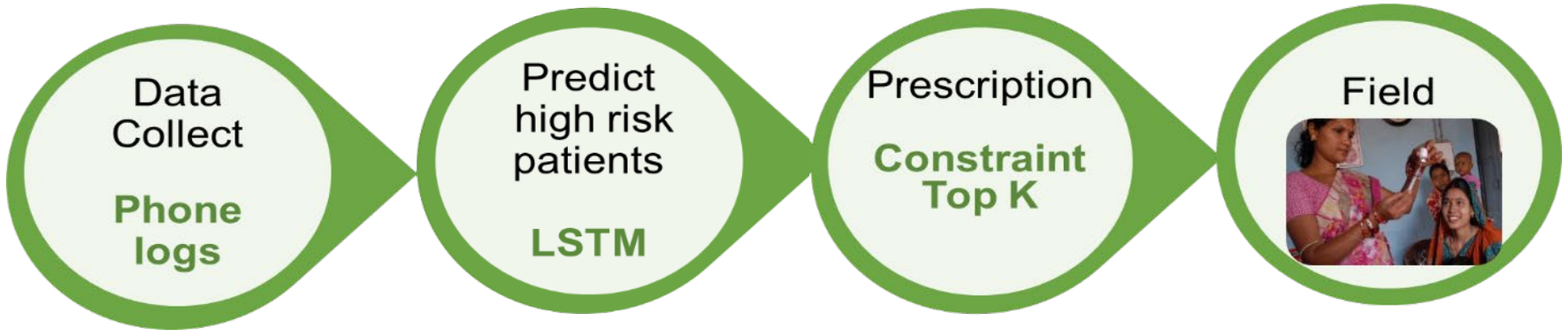
- *15K patients, 1.5M calls*

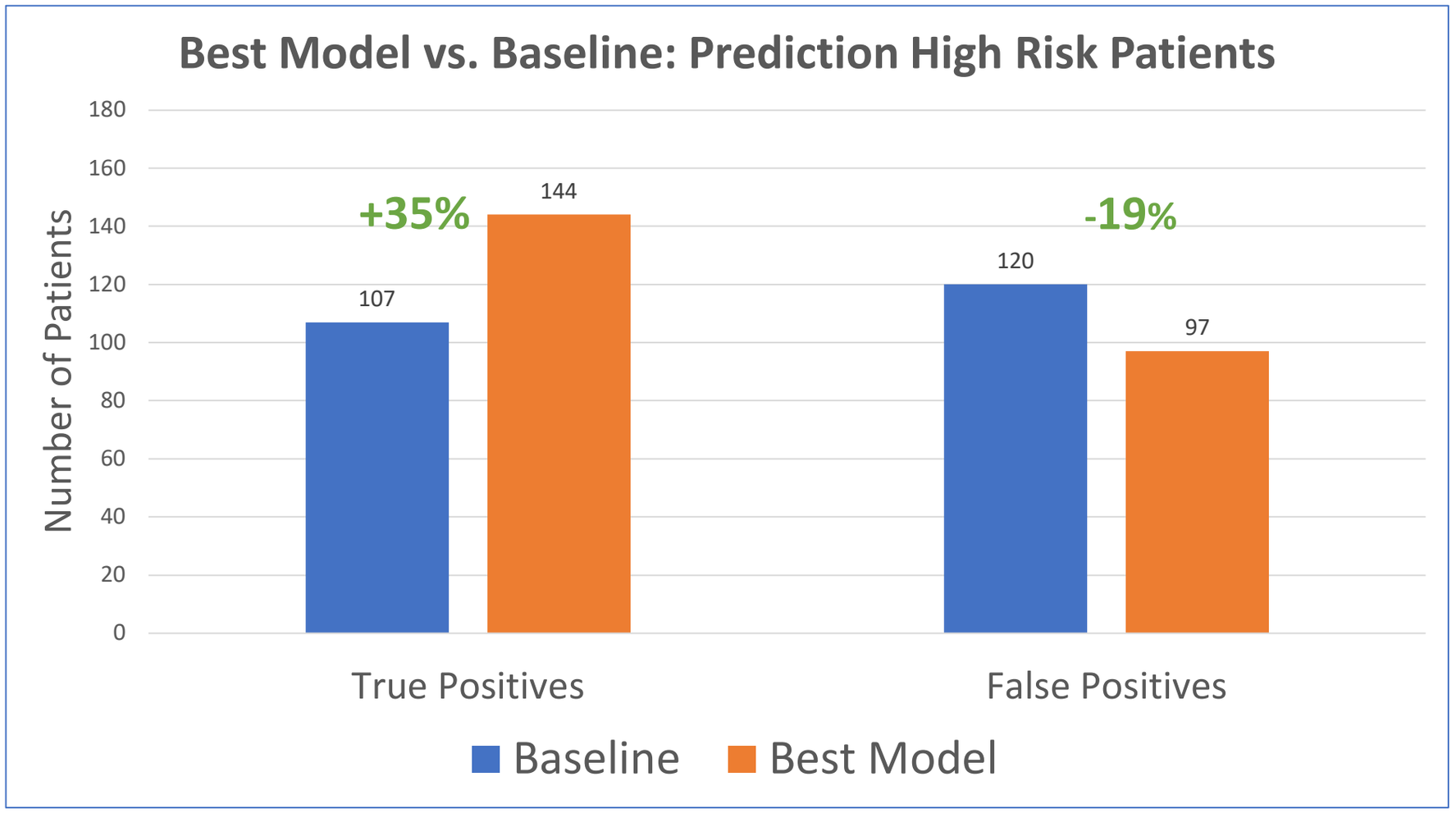
everwell



Increasing TB Treatment Adherence: Intervening before patients miss doses [2019]

Killian





Data from

State of Maharashtra

India

Integrating with Everwell's Platform

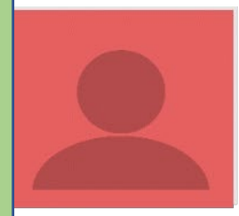
Killian

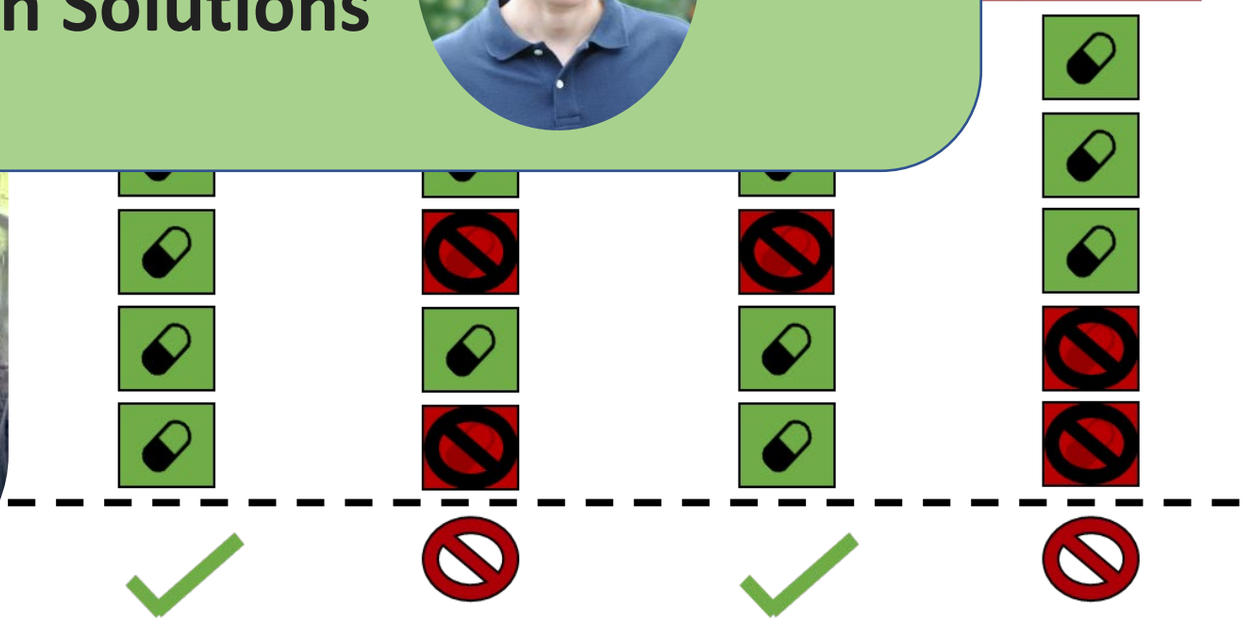
everwell

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