AI for Social Impact:
Results from deployments for public health and conservation

MILIND TAMBE

Director, Ctr for Research on Computation & Society, Harvard University

Google Research

Director "AI for Social Good", Google Research India

@MilindTambe_AI

AI & Multiagent Systems Research for Social Impact

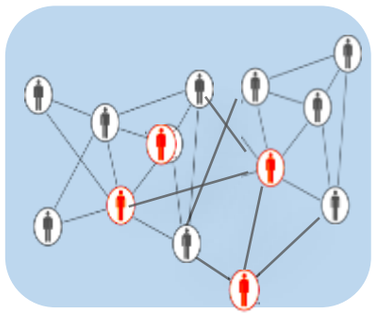
Public Health

Conservation

Public Safety and Security

Optimize Our Limited Intervention Resources

Lesson #1:
Achieving Social Impact and AI Innovation Go hand-in-hand



Social Networks & Bandits

Public Health

Green security games

Conservation

Public Safety & Security

Stackelberg security games

Lesson #2:
Partnerships with Communities, NGOs & Govt organization crucial

Empower non-profits to use AI tools; avoid being gatekeepers to AI4SI technology

LOS ANGELES LGBT CENTER

S.P.Y safe place for youth

my friend's place

armman Delivering India's Future

ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT

Wildlife Conservation Society

WWF

Air Shepherd The Lindbergh Foundation

Swasti THE HEALTH CATALYST

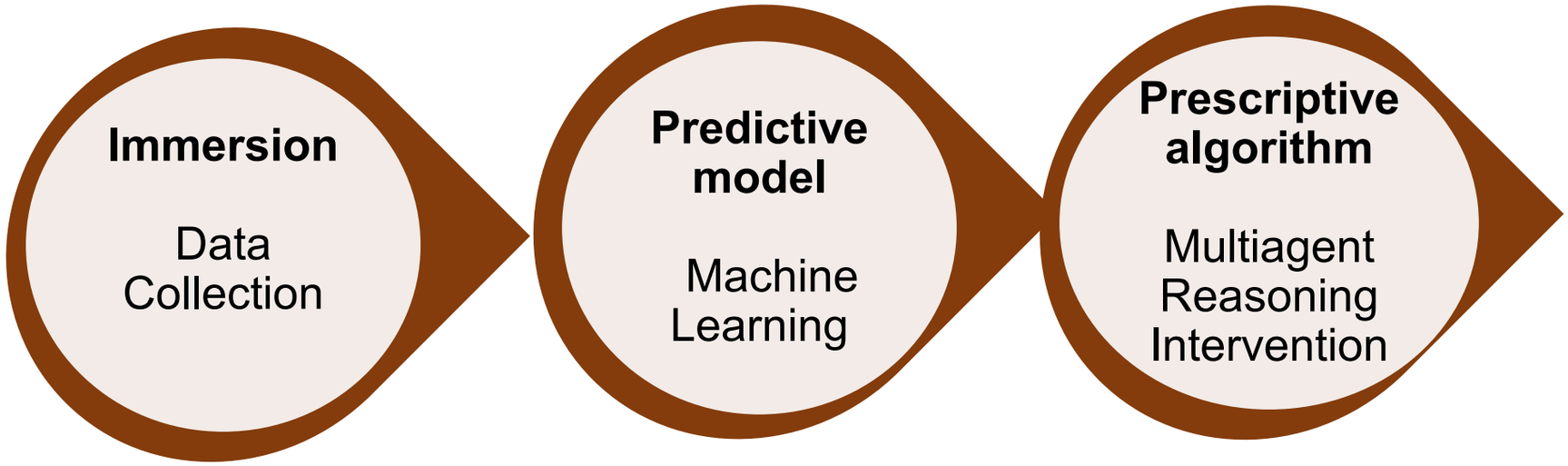
Wildlife Conservation Trust

SMART

everwell

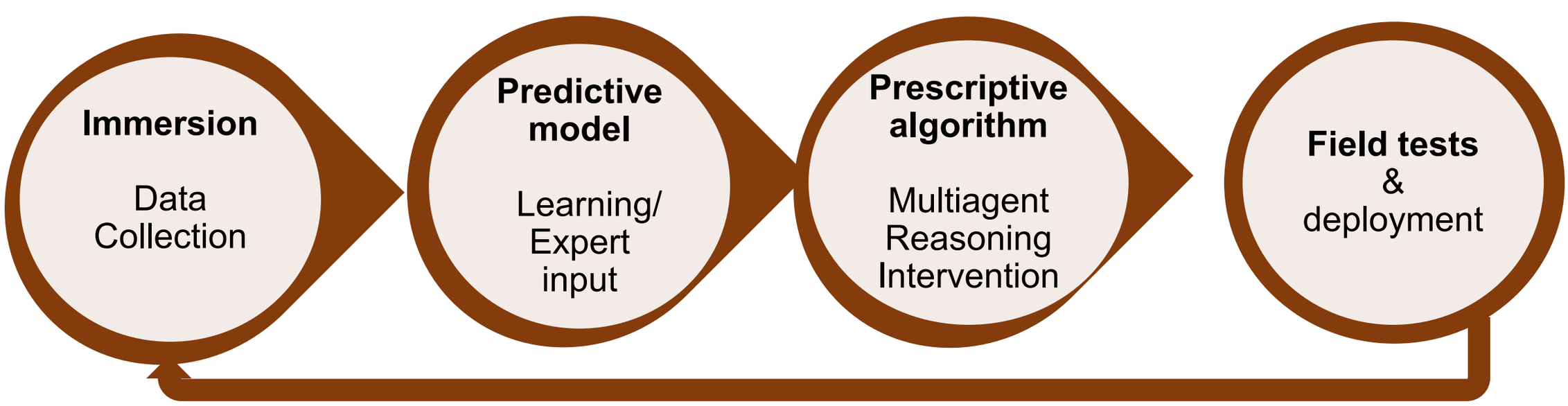
KhushiBaby

Lesson #3:
Data-to-deployment pipeline; not just improving algorithms



Lesson #3:
Data-to-deployment pipeline; not just improving algorithms

Field test & deployment: Social impact is a key objective



Outline

Public Health

- *Health information dissemination: Social networks*
- *Health program adherence: ML & Bandits*
- *COVID-19: Agent-based modeling*

Conservation

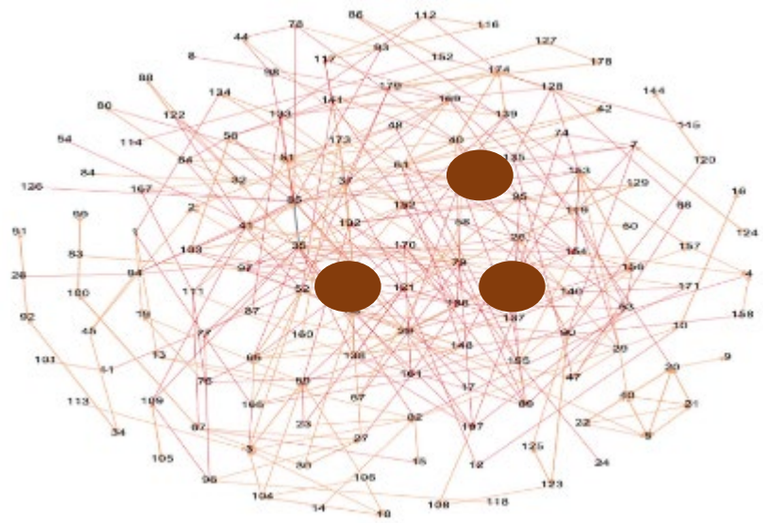
- Cover papers from 2017-now [AAMAS, AAAI, IJCAI, NeurIPS…]
- PhD students & postdocs highlighted

Information dissemination & behavior change
Optimizing Limited Intervention (Social Worker) Resources

Prevent HIV in youth experiencing homelessness: HIV 10x housed population

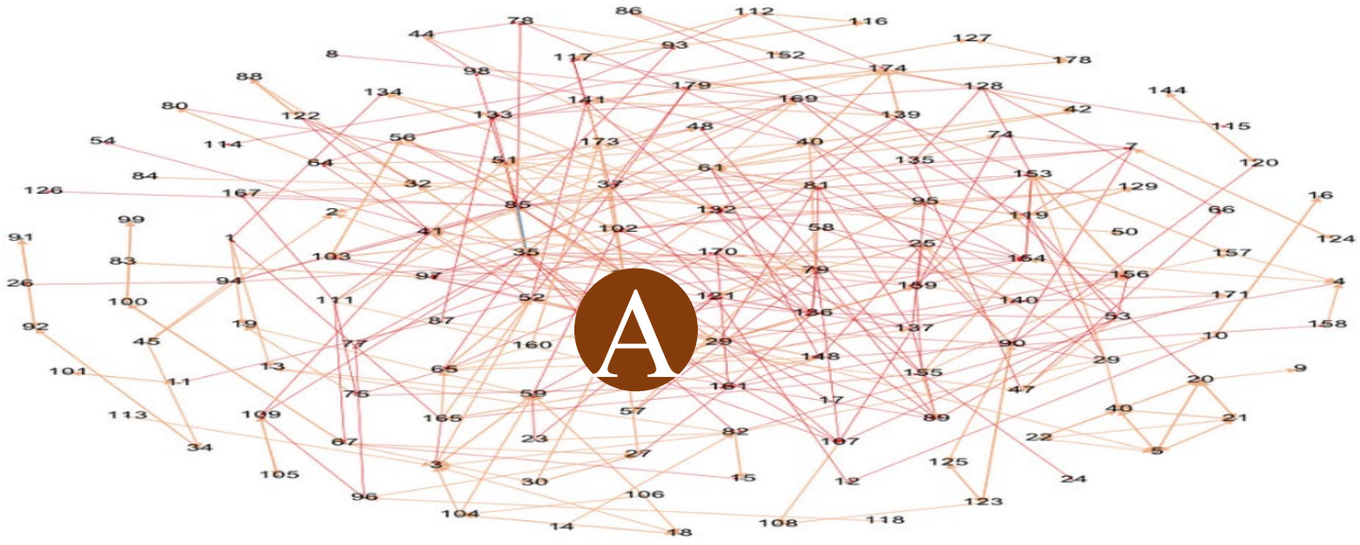
- ***Shelters**: Limited number of peer leaders to spread HIV information in social networks*
- *"Real" face-to-face interactions; not Facebook etc*

Influence Maximization in Social Networks

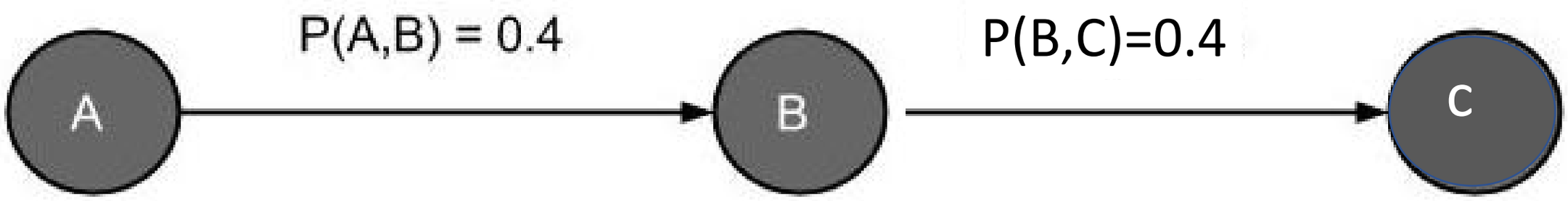


- Given:
  - Social network Graph G
  - Choose K “peer leader” nodes
  - Assume: Independent cascade model of information spread
- Objective:
  - Maximize expected number of influenced nodes

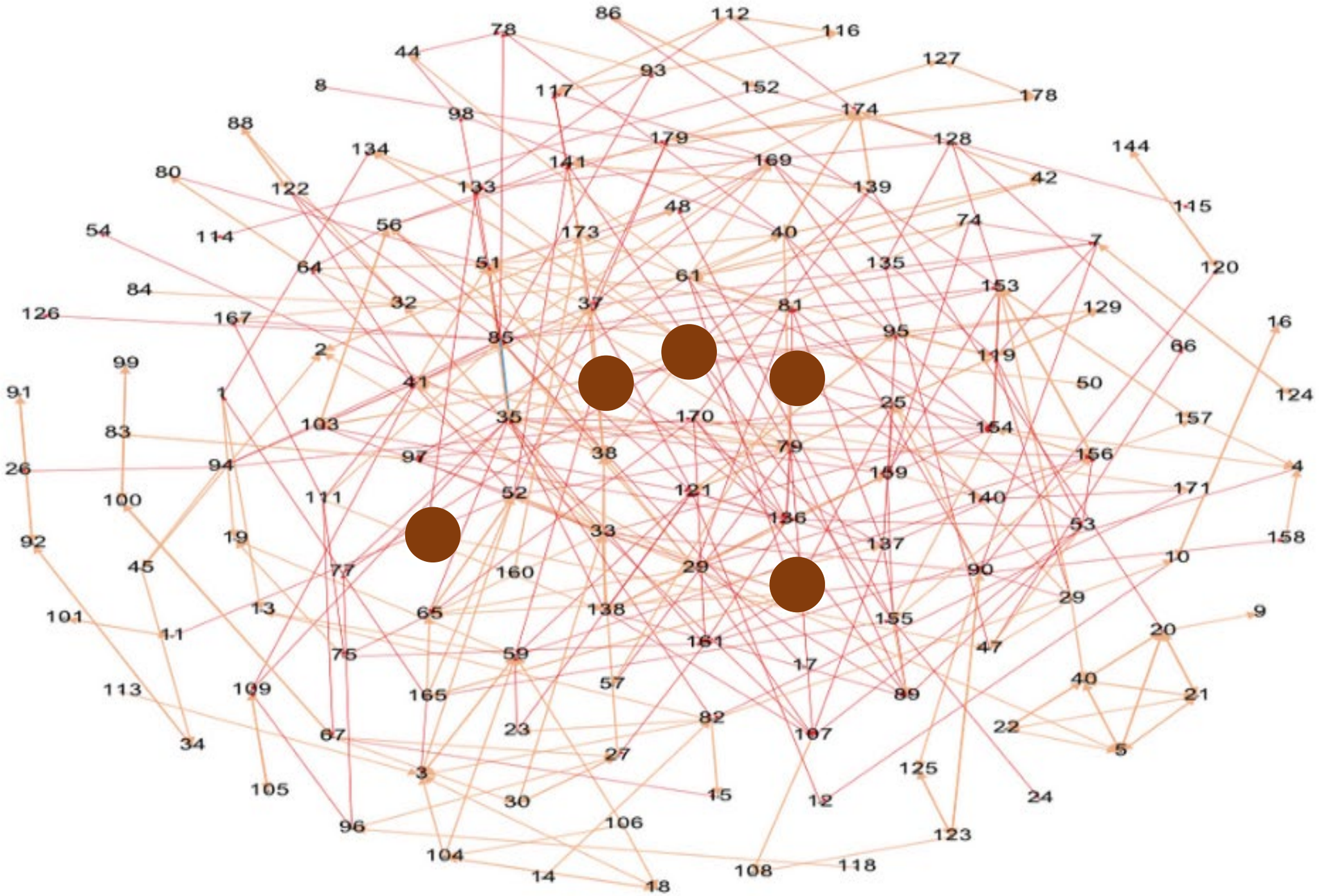
Independent Cascade Model



- Propagation Probability (for each edge)



Influence Maximization (Budget = 5 nodes)



Lesson #4:Embrace interdisciplinary research

Influence Maximization in Social Networks
Three Key Challenges Combined Together

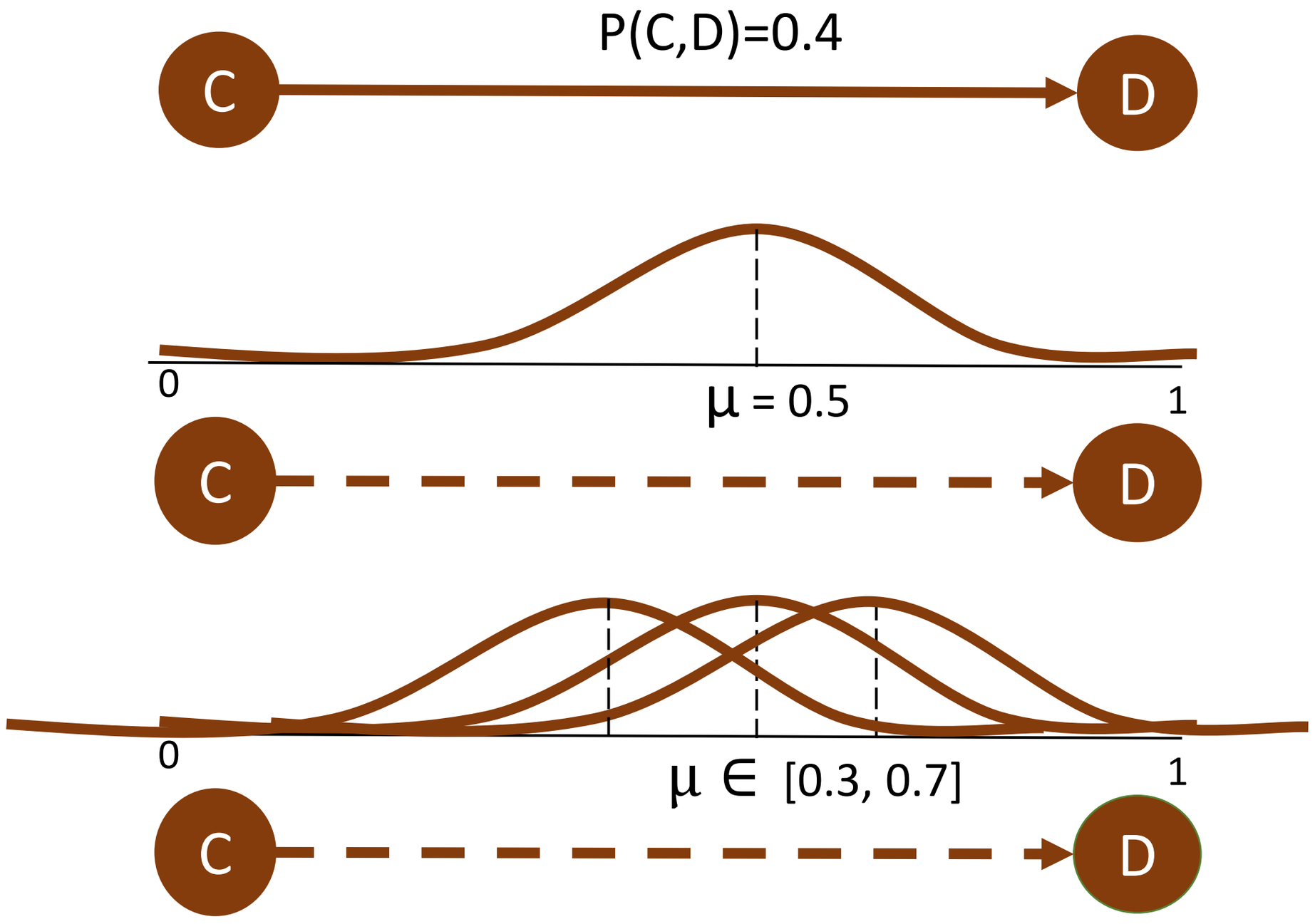
Research challenges in AI for social good?

***Lesson #5**: Lack of data & uncertainty is a feature (research challenge), not a bug*

- Uncertainty in propagation probability over edges
- Unknown social network, limited query budget to uncover network
- Multi-step dynamic policies to handle peer leader “no shows”

Sketch some ways we solve these problems

Challenge 1: Uncertainty in Real-world Physical Social Networks



Robust Influence Maximization

(AAMAS 2017)

Wilder

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

$$\max_{x \in \Delta^{|P|}} \min_{\mu,\sigma} \sum x_p \frac{(Outcome(p))}{OPT(\mu,\sigma)}$$

Algorithm

Choose Peer Leaders p ∈ P generating mixed strategy "$x \in \Delta^{|P|}$"

vs

Nature

Chooses parameters

μ,σ

HEALER Algorithm
Robust Influence Maximization
(AAMAS 2017)


Wilder

- Iterative algorithm: Double oracle

Nature

Influencer

	Params #1	Params #2	Params #3
Policy #1	0.8, -0.8	0.3, -0.3	0.4, -0.4
Policy #2	0.7, -0.7	0.5, -0.5	0.6, -0.6
Policy #3	0.6, -0.6	0.4, -0.4	0.7, -0.7

Influencer's oracle

\	Params #1	Params #2
Policy #1	0.8, -0.8	0.3, -0.3
Policy #2	0.7, -0.7	0.5, -0.5
Policy #3	0.6, -0.6	0.4, -0.4

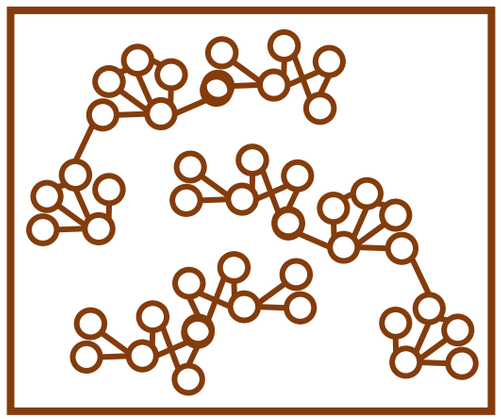
Nature's oracle

	Params #1	Params #2	Params #3
Policy #1	0.8, -0.8	0.3, -0.3	0.4, -0.4
Policy #2	0.7, -0.7	0.5, -0.5	0.6, -0.6
Policy #3	0.6, -0.6	0.4, -0.4	0.7, -0.7

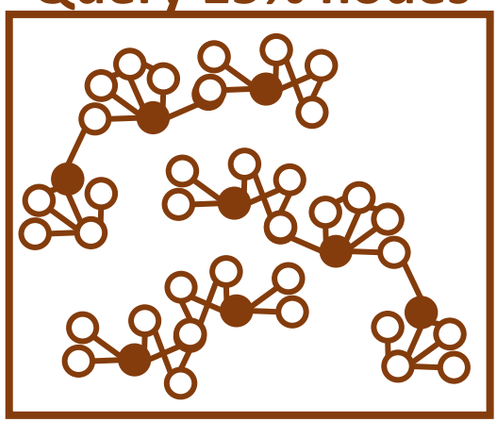
Challenge 3:
Sampling Networks: Exploratory Influence Maximization
(AAAI 2018)


Wilder

Data collection costly



Query 15% nodes



Sampling Algorithm

Sample node randomly & estimate size of its community;
Choose seeds from largest K communities

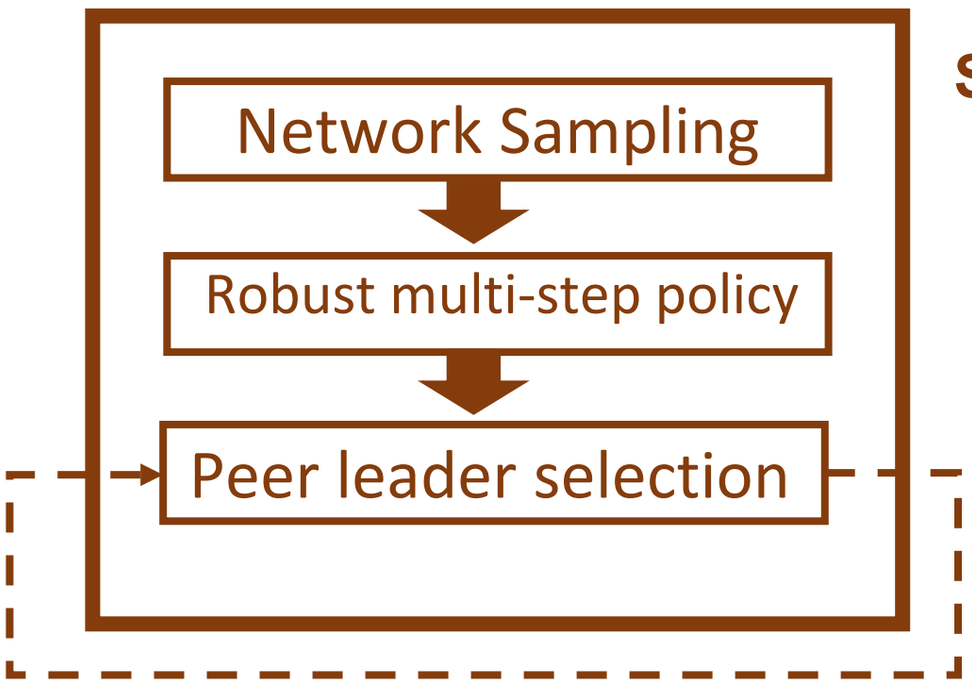
- Query 15% of nodes in the population
- Output K peer leader nodes to spread influence
- Perform similar to OPT, best influence spread with full network

(*)Community structured: drawn from a stochastic block model

“Sampling-HEALER”
Pilot tests with Homeless Youth
(IJCAI 2018)


Yadav


Wilder



Sampling-HEALER

Observe peer leaders present/absent

12 peer leaders

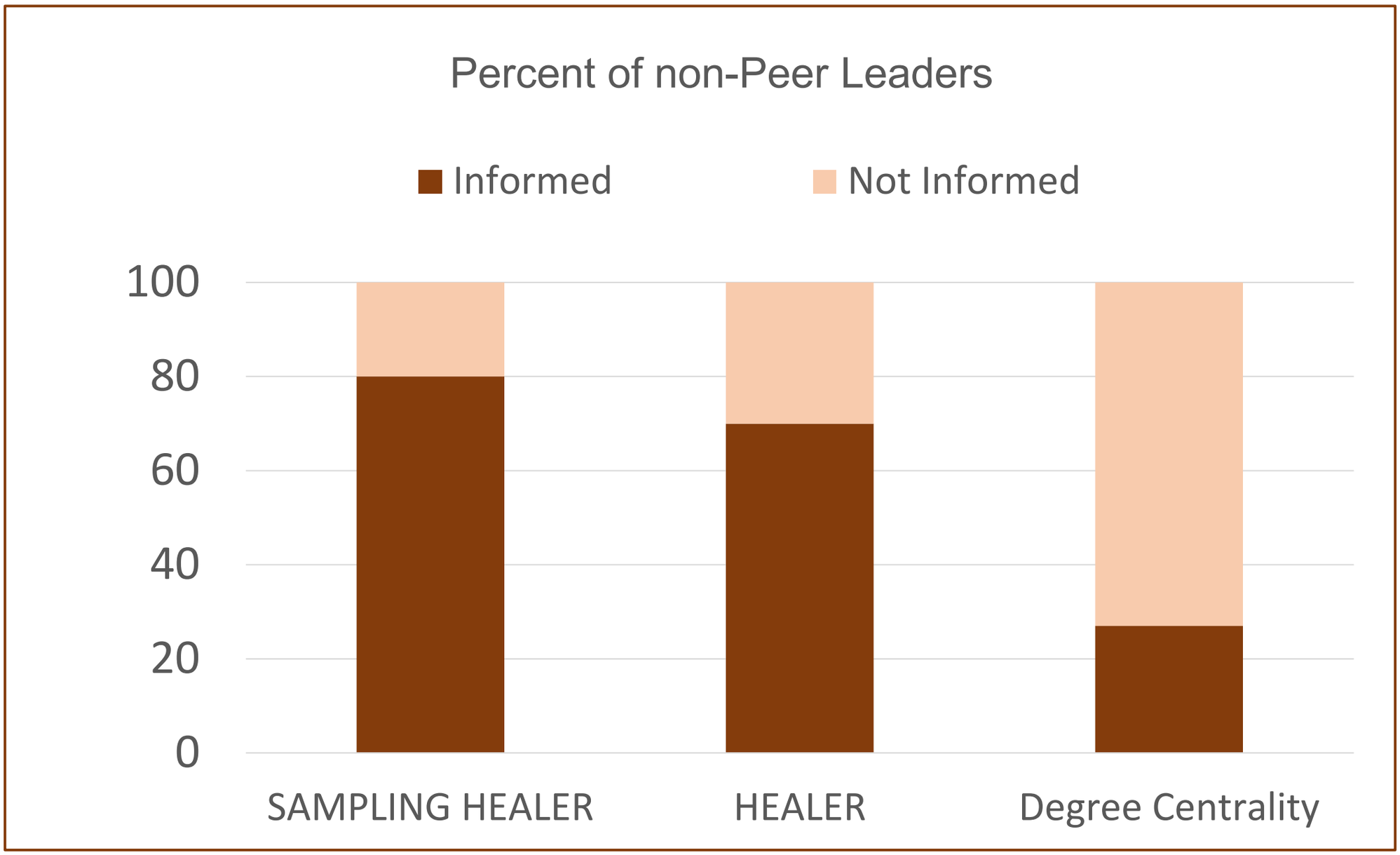
Sampling HEALER (Sampled Network)	HEALER (Full Network)	DEGREE CENTRALITY (Full Network)
60 youth	62 youth	55 youth

Results: Pilot Studies

(Journal of Society of Social Work & Research 2018)

Yadav

Wilder



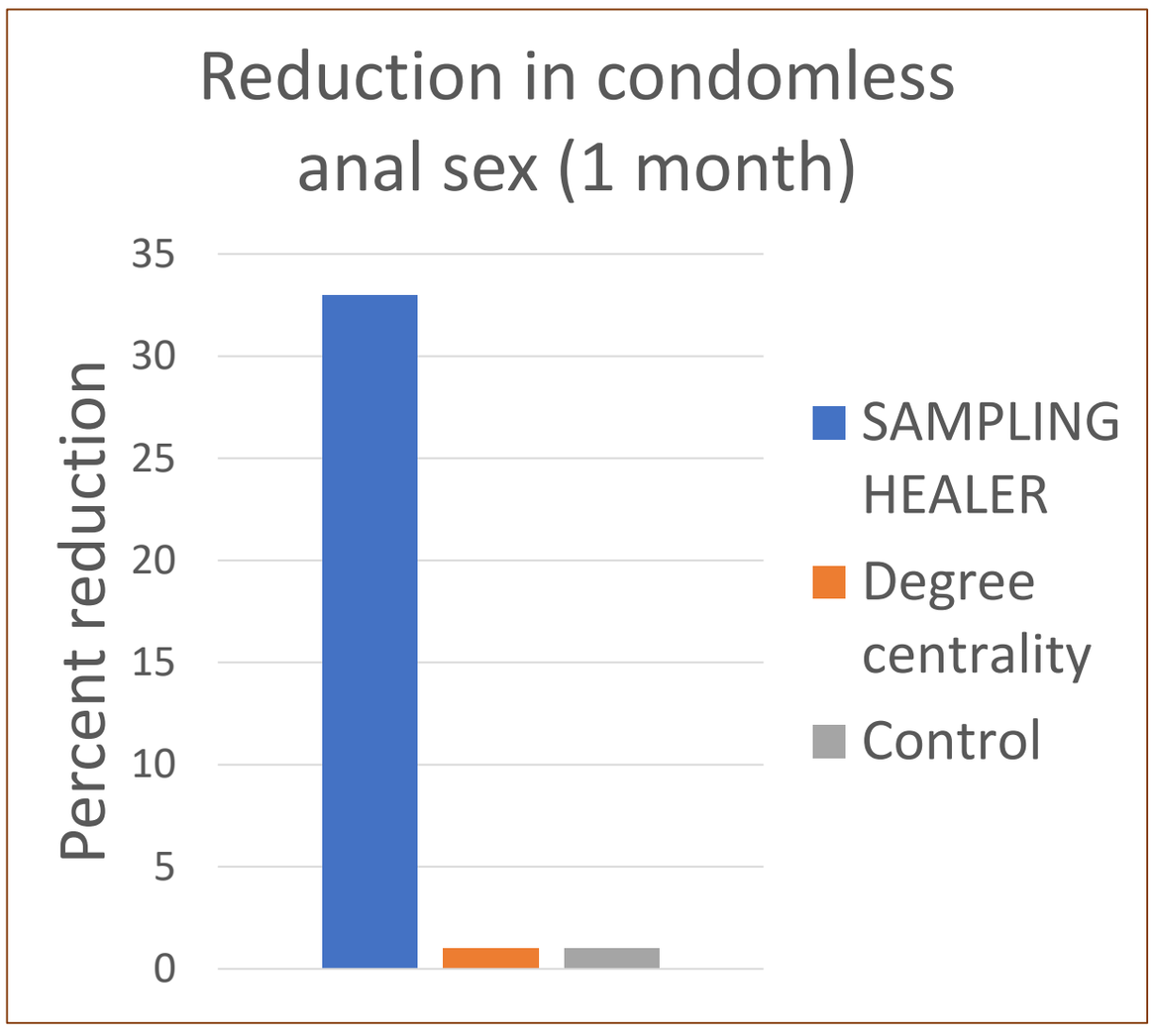
Results of 750 Youth Study [with Prof. Eric Rice]
Actual Change in Behavior?
(AAAI 2021)

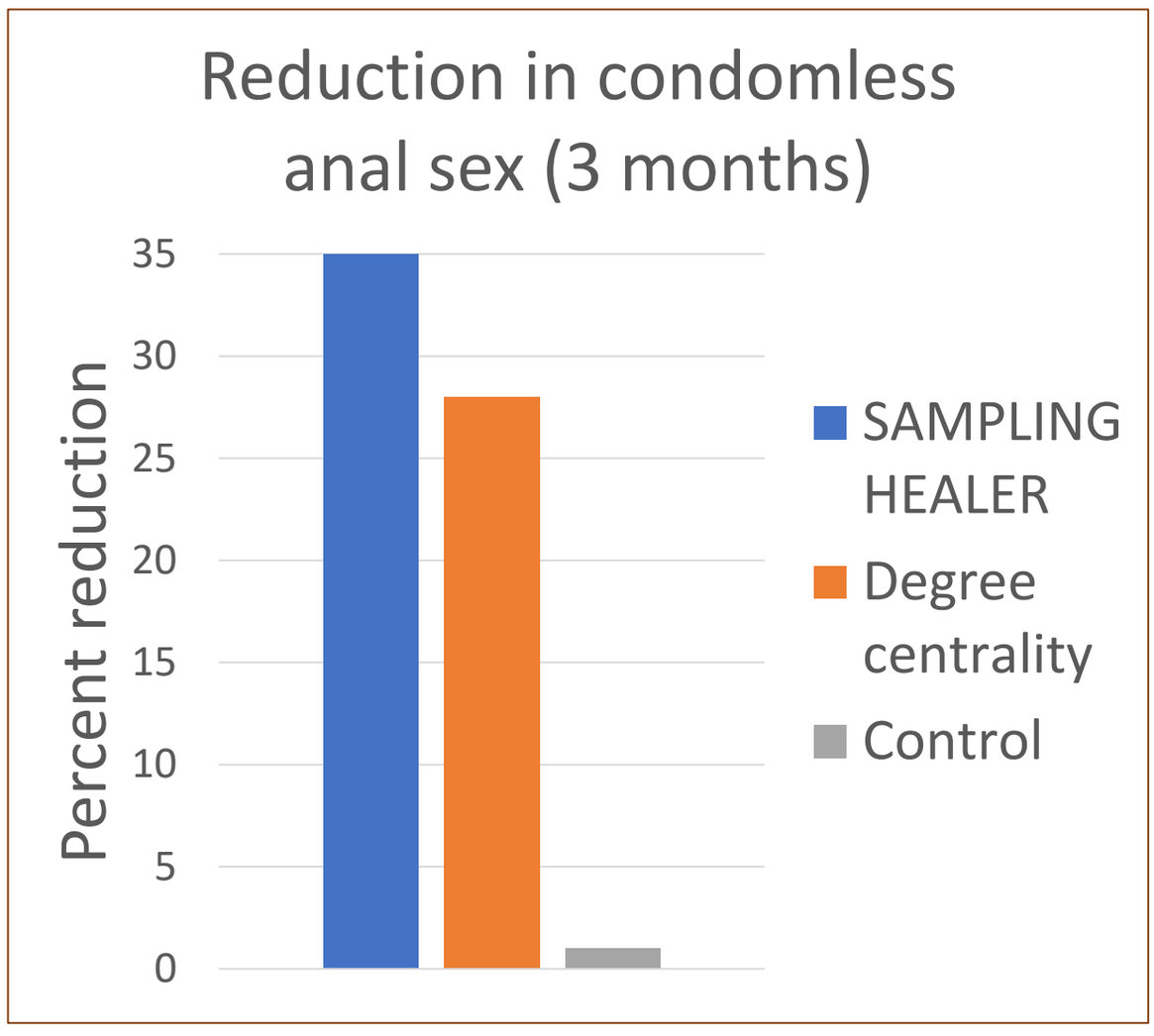
First large-scale application of influence maximization for public health

my friend's place

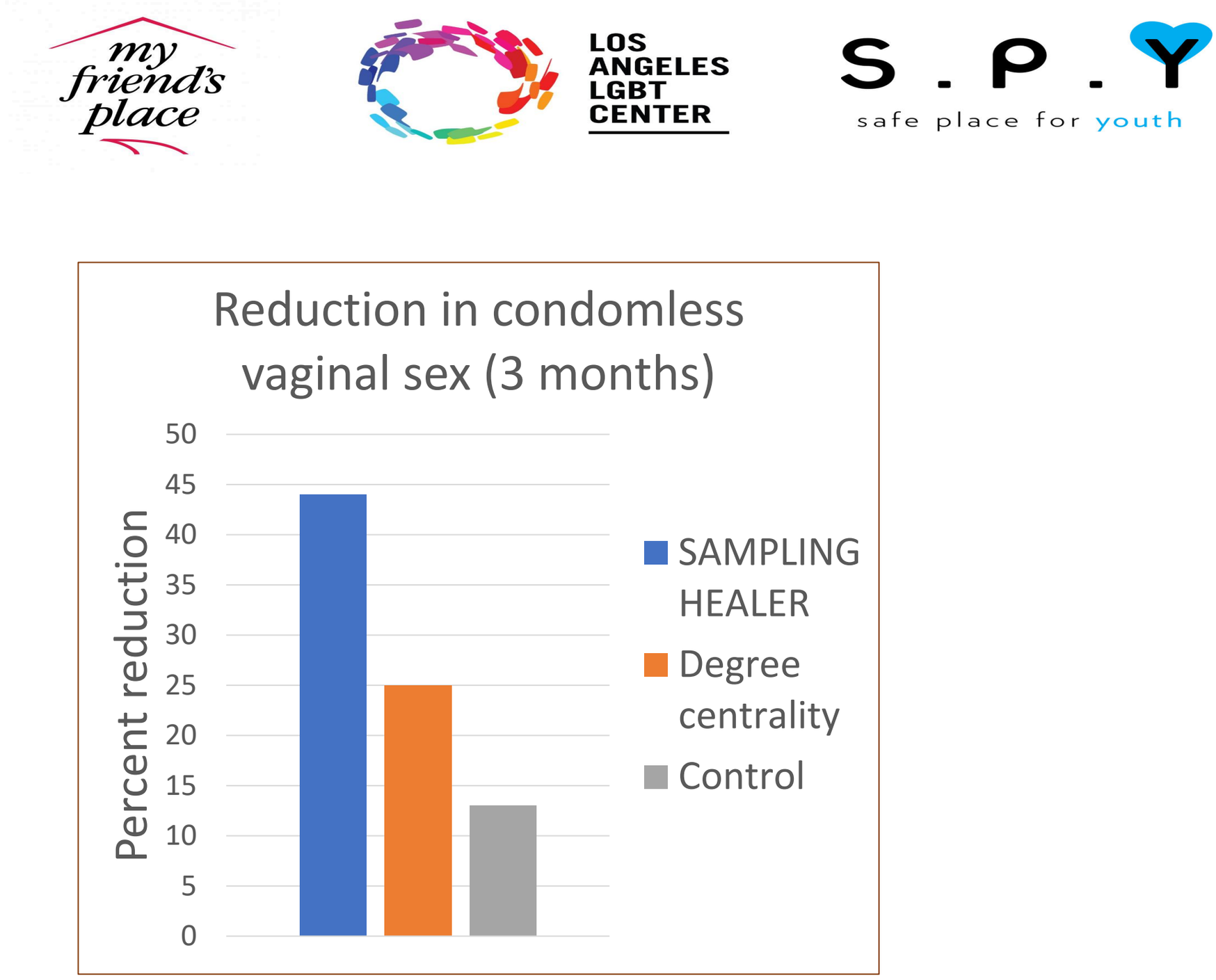
LOS ANGELES LGBT CENTER

S.P.Y safe place for youth





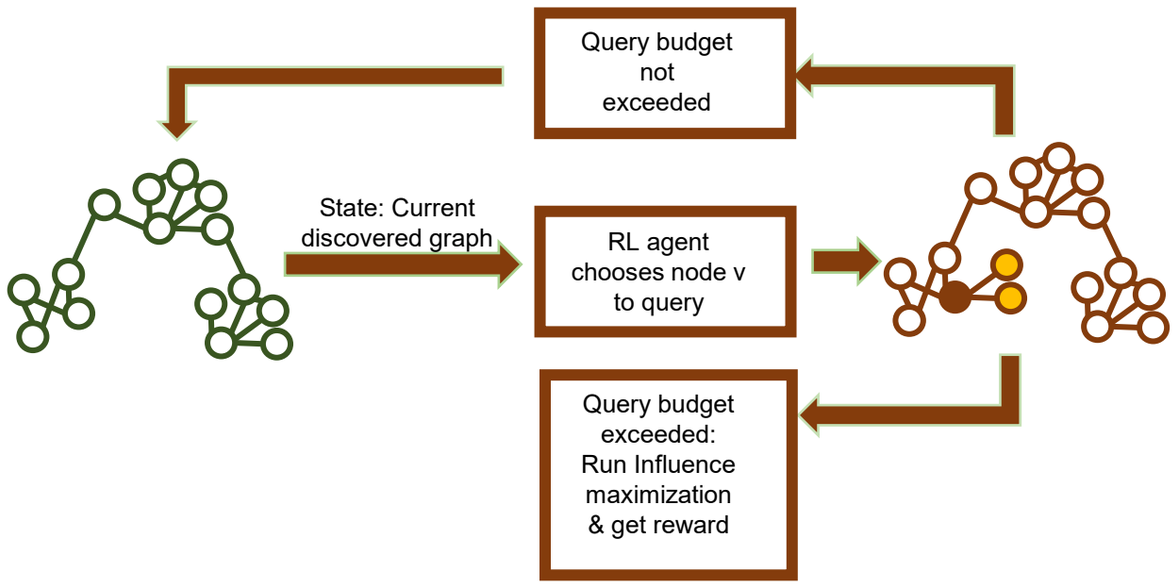
Results of 750 Youth Study [with Prof. Eric Rice]



What our collaborators are saying:

Next steps:RL for Influence Maximization in Social Networks

(with B. Ravindran & team, AAMAS 2020)



Network Family	Improve %
Rural	23.76
Animal	26.6
Retweet	19.7
Homeless	7.91

Outline

Public Health

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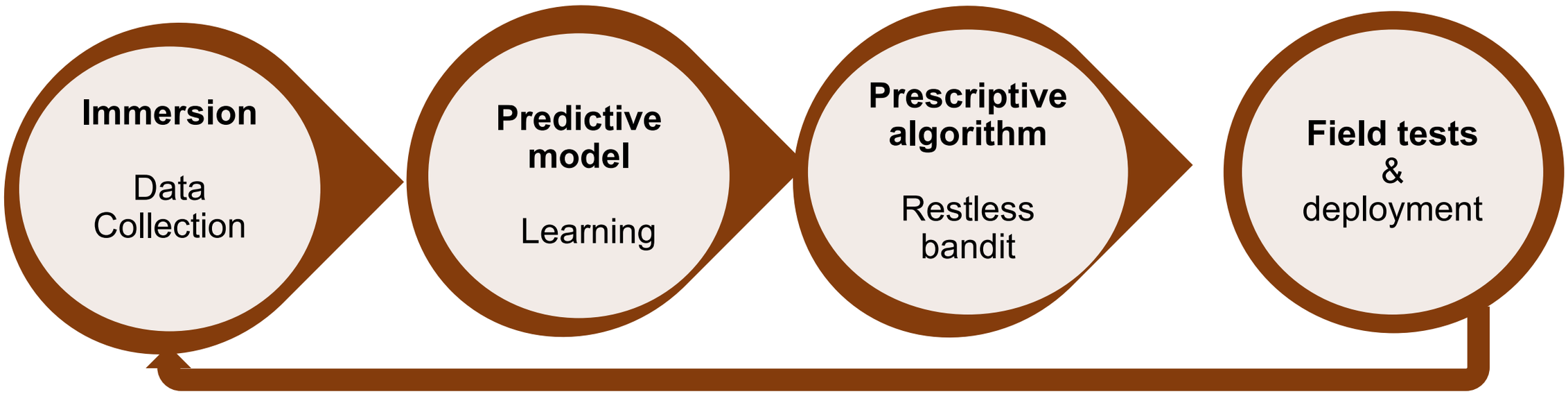
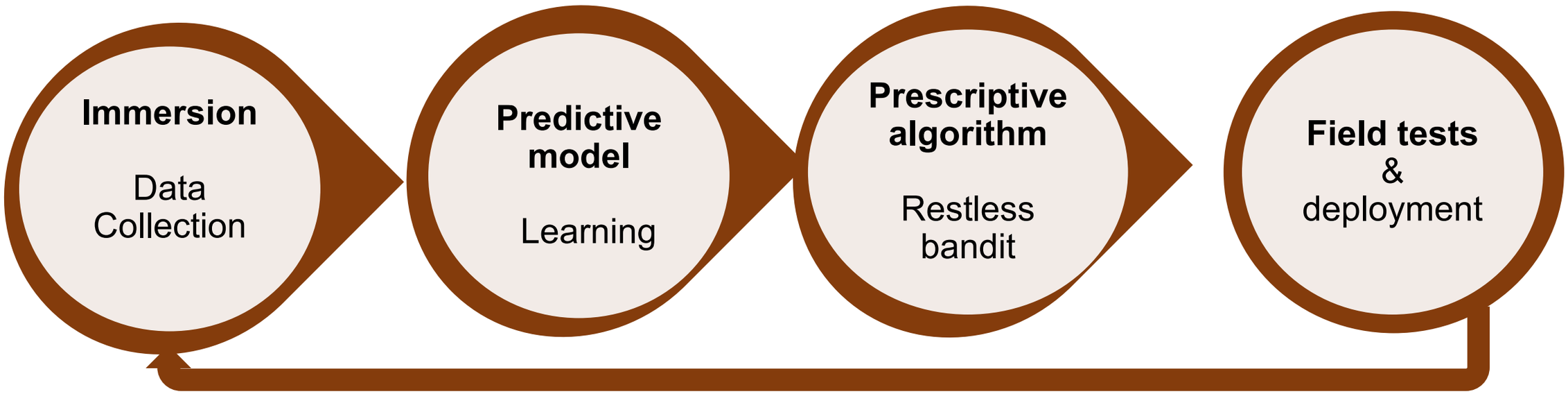
- *Health program adherence: ML & Bandits*
- *COVID-19: Agent-based modeling*

Conservation

Intervention Reasoning: Active Adherence Monitoring



Intervention Reasoning: Active Adherence Monitoring



Health Program Adherence
Maternal & Child Care in India

(IJCAI 2021)

Woman dies in childbirth every 15 min; 4 of 10 children too thin/short

18 Million women

Weekly 3 minute call to new/expecting moms

mMitra: Significant benefits 2.2 million women enrolled

- *Unfortunately, significant fraction low-listeners or drop-outs*

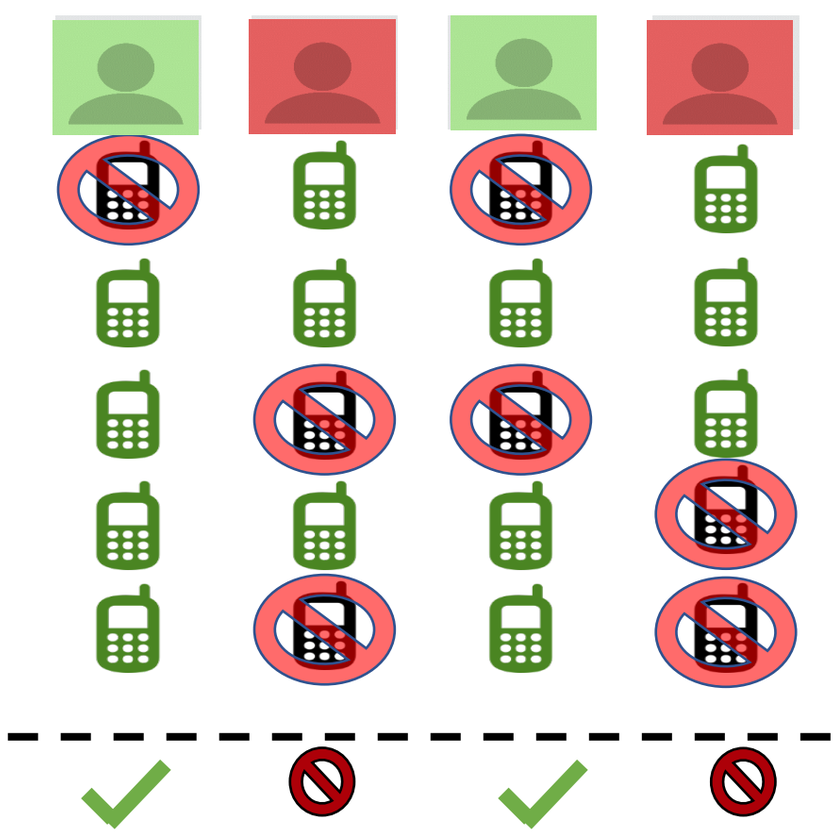
Passive Adherence Monitoring
Maternal & Child Care in India

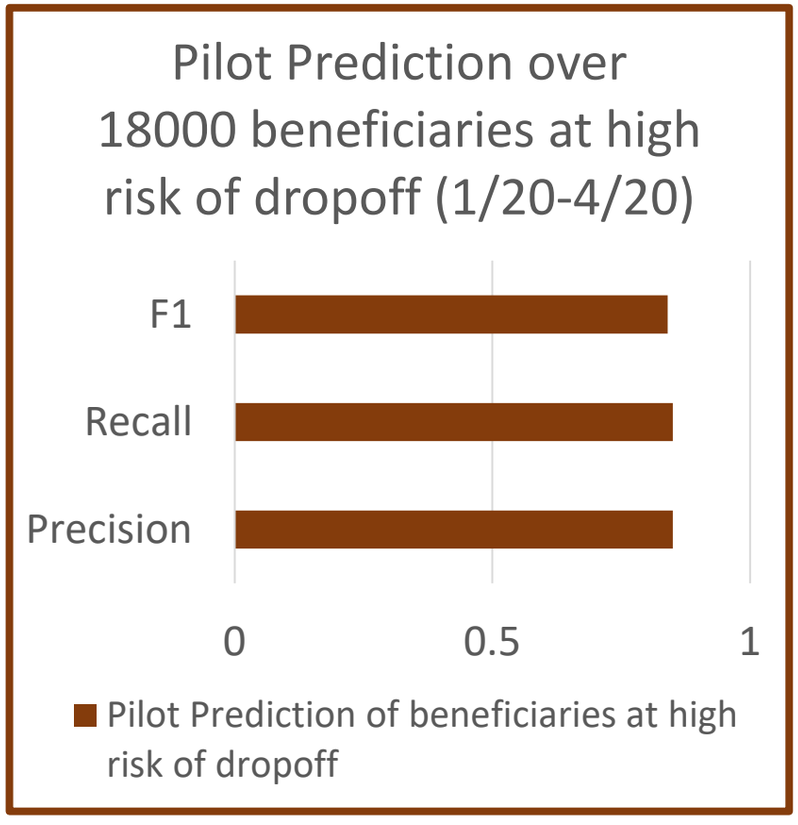
(with B Ravindran IIT Madras)

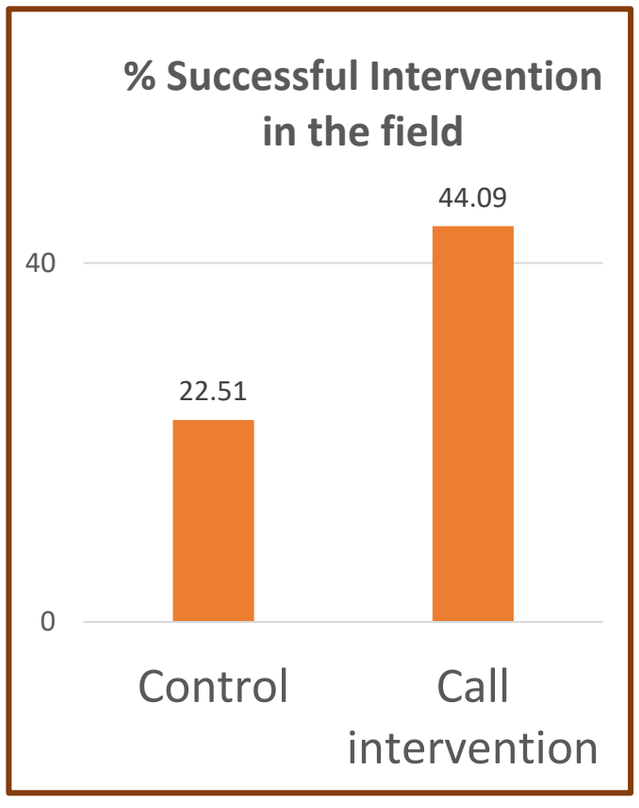
Classifier to predict beneficiaries drop out? So ARMMAN can focus interventions

- *Results of pilot with 18000 beneficiaries: High precision, recall, accuracy*
- *Field trial with 8000 beneficiaries: Call intervention helps*

- ***Prediction software in use to help 300,000 beneficiaries in mMitra***

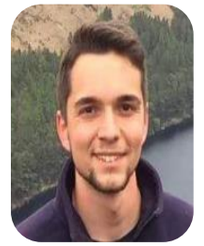






Passive Adherence Monitoring Preventing Tuberculosis in India

(KDD 2019)



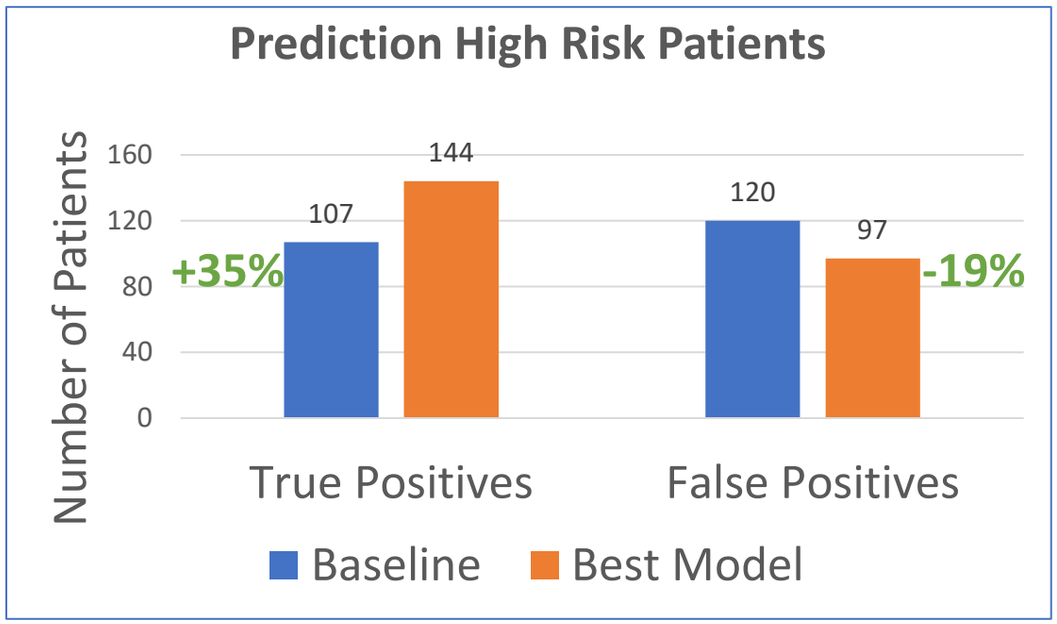
Killian

Tuberculosis (TB): ~500,000 deaths/year, ~3M infected in India

- *Predict adherence risk from phone call patterns for early intervention?*

TB Treatment
6 months of pills

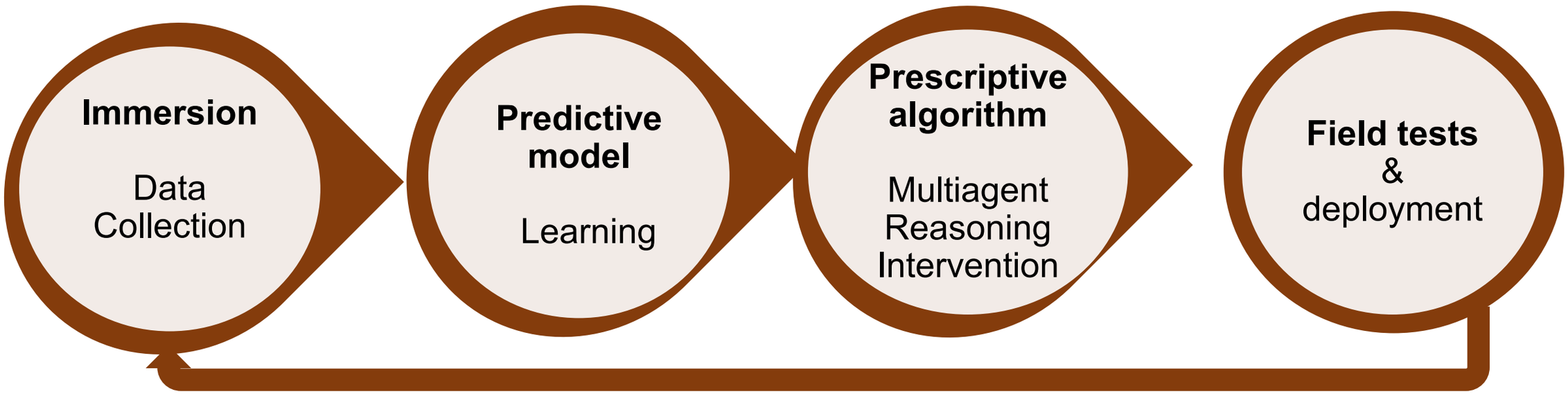
Track adherence
via daily phone calls



Results Mumbai, India:
15,000 patients, 1.5 Million calls

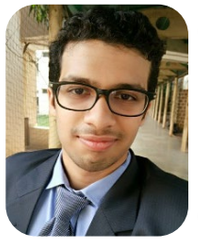
everwell

Intervention Reasoning: Active Adherence Monitoring



Intervention Scheduling with Scarce Data: Active Adherence Monitoring

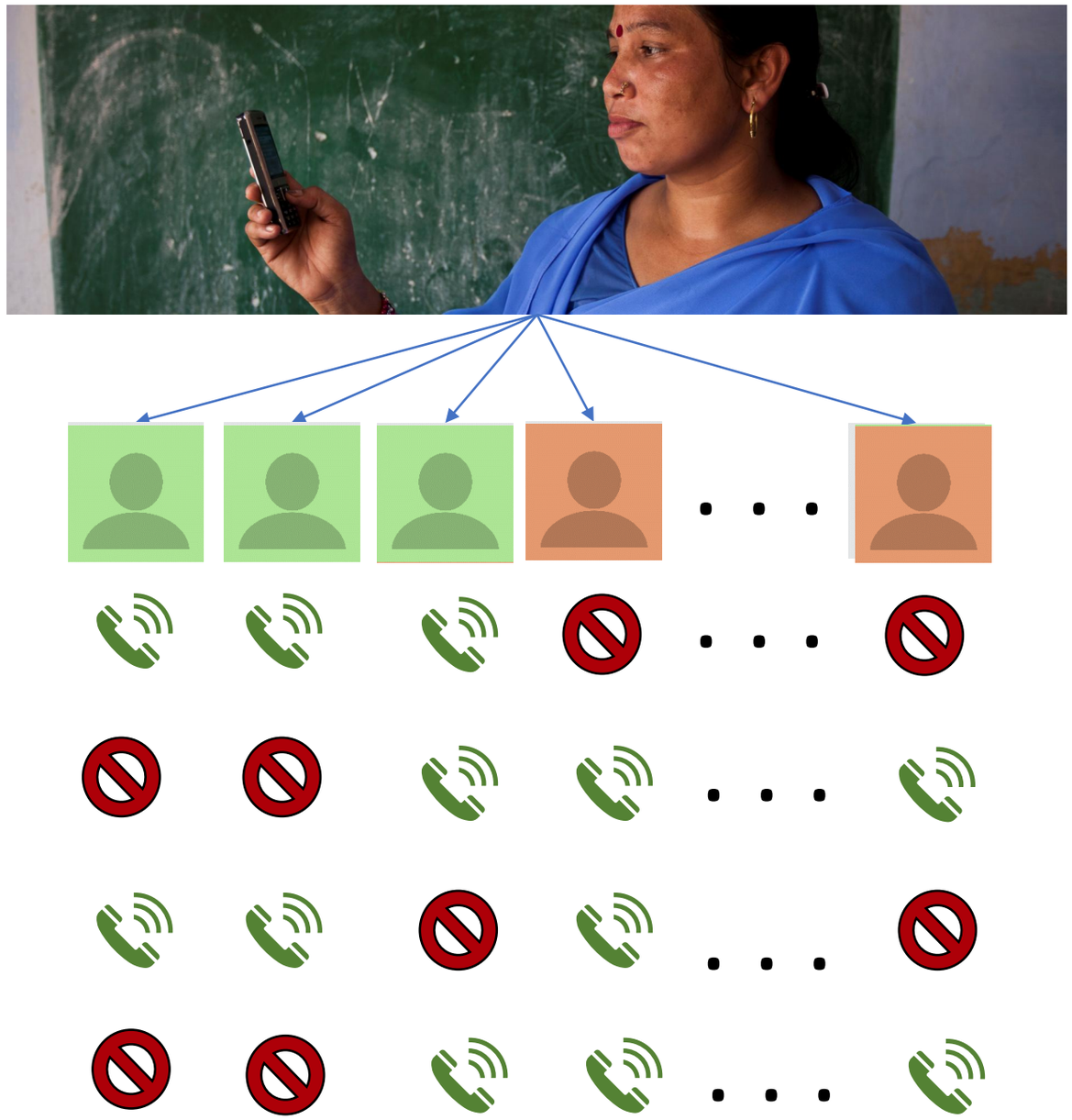
(NeurIPS 2020)


Mate


Killian

Challenge:

- *Large number of patients (N)*
- *Can only call K patients per day.*
- *Which K?*



Approach: "Restless bandit"

- *Each arm (patient) latent state {0, 1}*
- *0= not-adhering; 1= adhering*

Goal: Policy for K patients to call per day

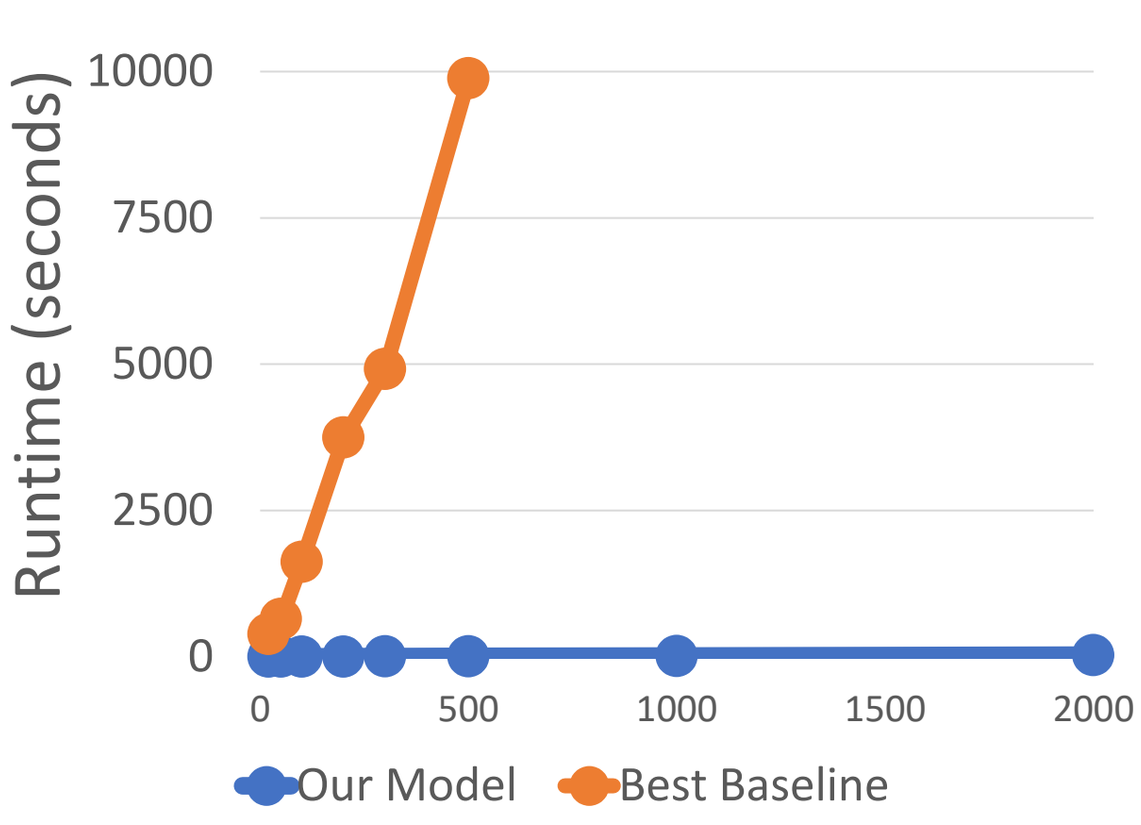
Photo Credit: IntraHealth International (CC BY-NC-SA 3.0 via https://www.intrahealth.org/)

New Fast Algorithm: Collapsing Bandits

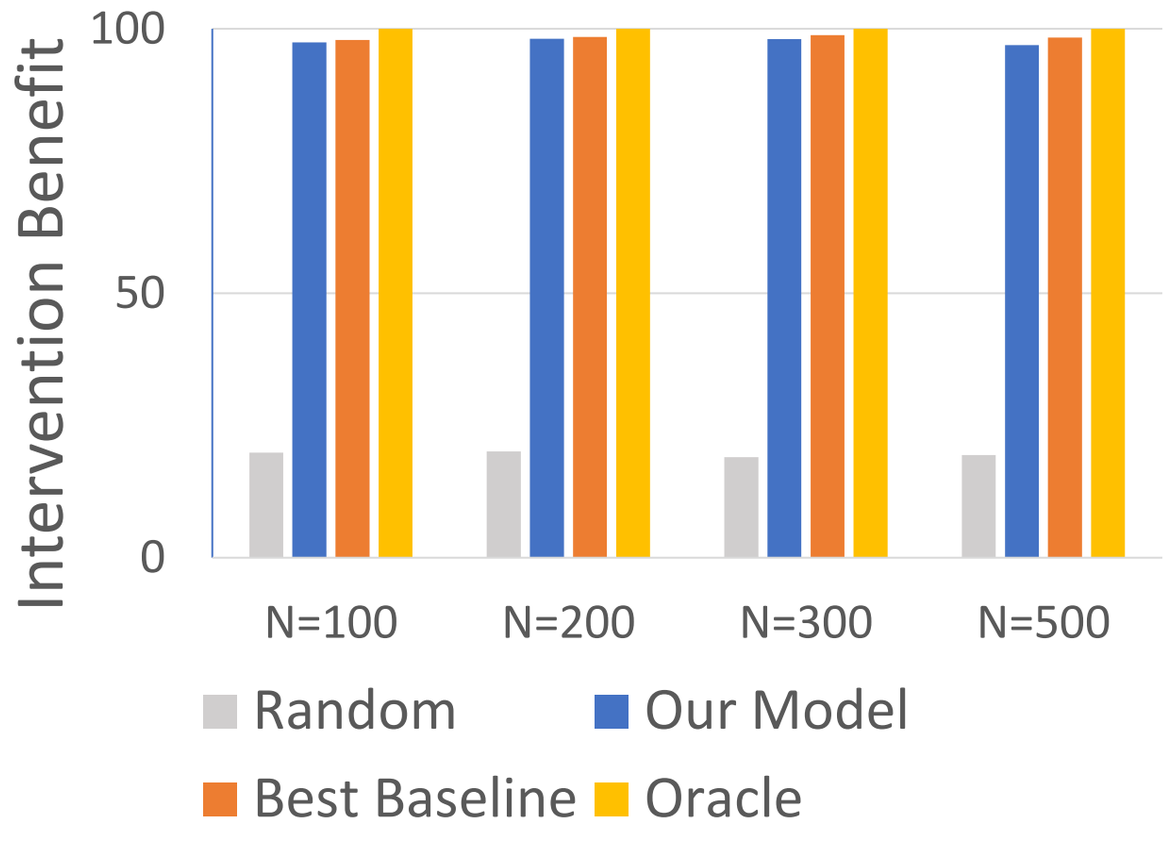

Mate Killian

- ***Orders of magnitude speedup with no solution quality loss***
- ***ORANGE = Best baseline***
- ***Blue = Our model***

Runtime



Solution Quality



New Directions in Restless Bandits

Restless bandits for intervention:

- *20000 subject trial*

Outline

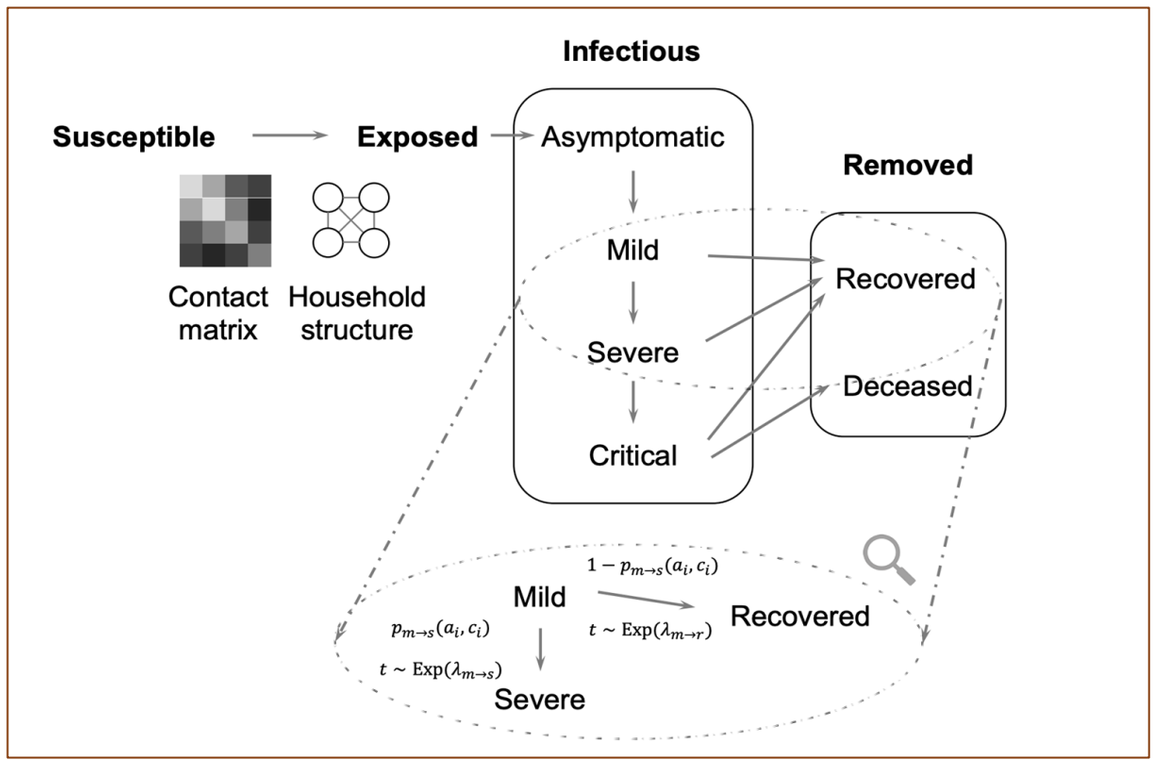
Public Health

- *Health information dissemination: Social networks*
- *Health program adherence: ML & Bandits*
- *COVID-19: Agent-based modeling*

Conservation

COVID-19: Agent-based Simulation Model

Wilder



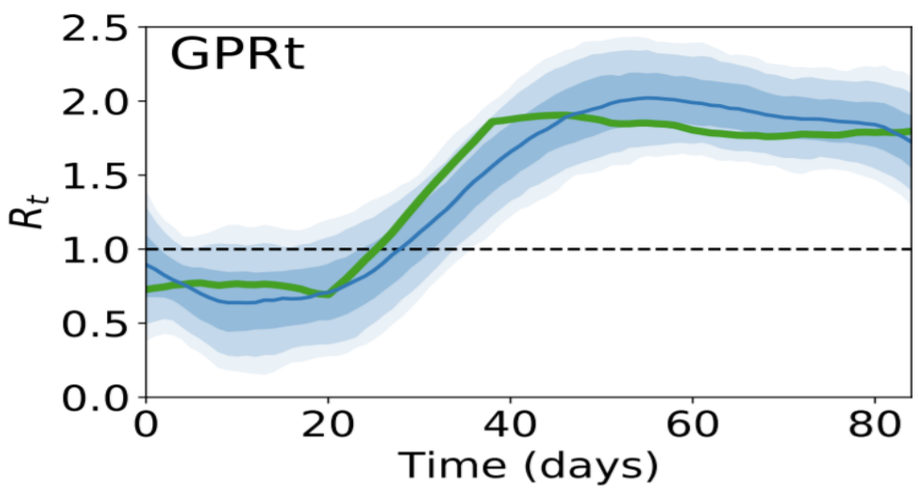
PNAS Proceedings of the National Academy of Sciences of the United States of America

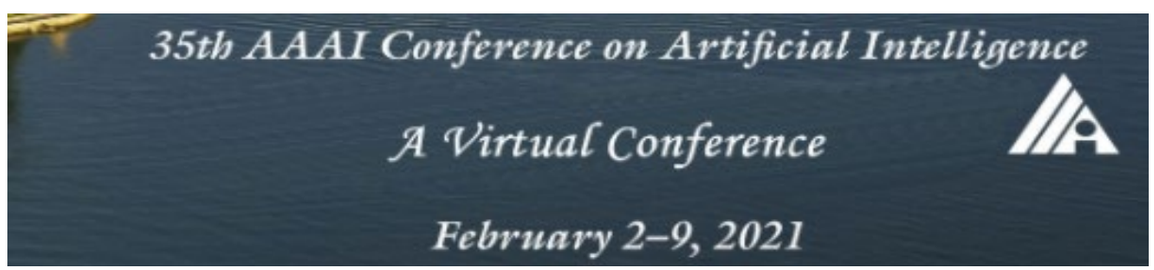
RESEARCH ARTICLE

Modeling between-population variation in COVID-19 dynamics in Hubei, Lombardy, and New York City

Bryan Wilder, Marie Charpignon, Jackson A. Killian, Han-Ching Ou, Aditya Mate, Shahin Jabbari, Andrew Perrault, Angel N. Desai, Milind Tambe, and Maimuna S. Majumder

PNAS October 13, 2020 117 (41) 25904-25910; first published September 24, 2020;
https://doi.org/10.1073/pnas.2010651117





Tracking disease outbreaks from sparse data with Bayesian inference

Bryan Wilder,[1] Michael Mina[2], Milind Tambe[1]
[1] John A. Paulson School of Engineering and Applied Sciences, Harvard University
[2] T.H. Chan School of Public Health, Harvard University
bwilder@g.harvard.edu, mmina@hsph.harvard.edu, milind_tambe@harvard.edu

COVID Testing Policy: Accuracy vs Ease

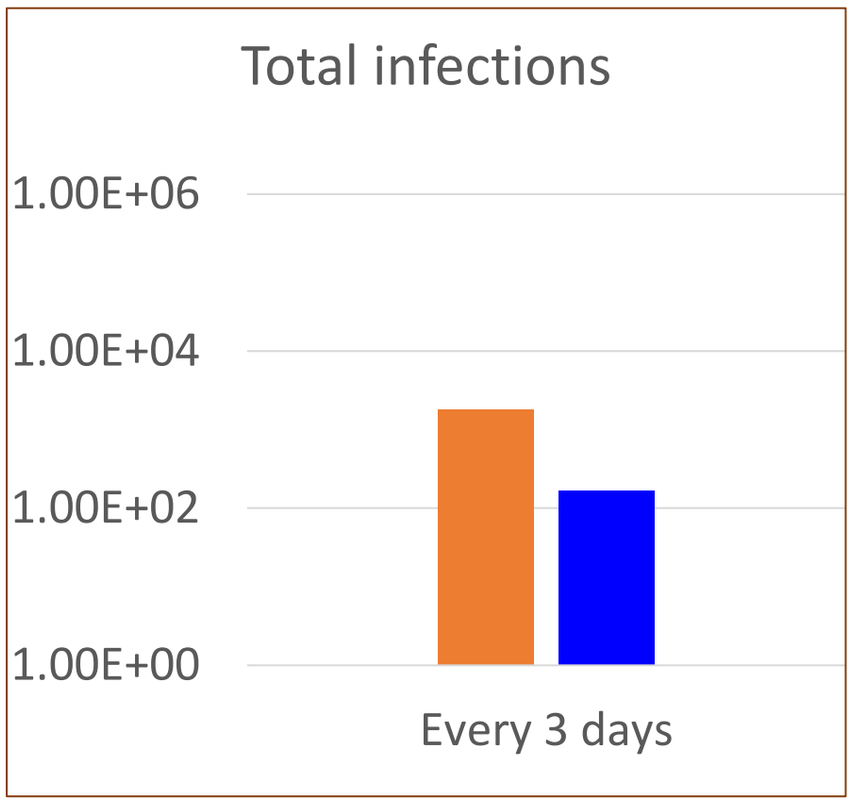
(Science Advances, 2020) with Prof. Michael Mina

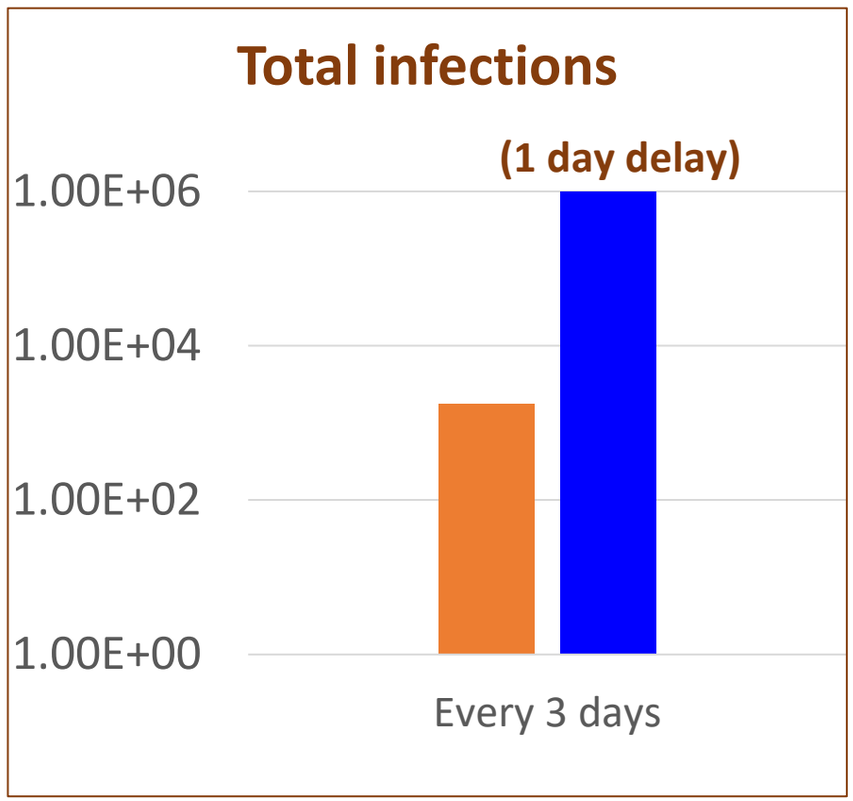
Wilder

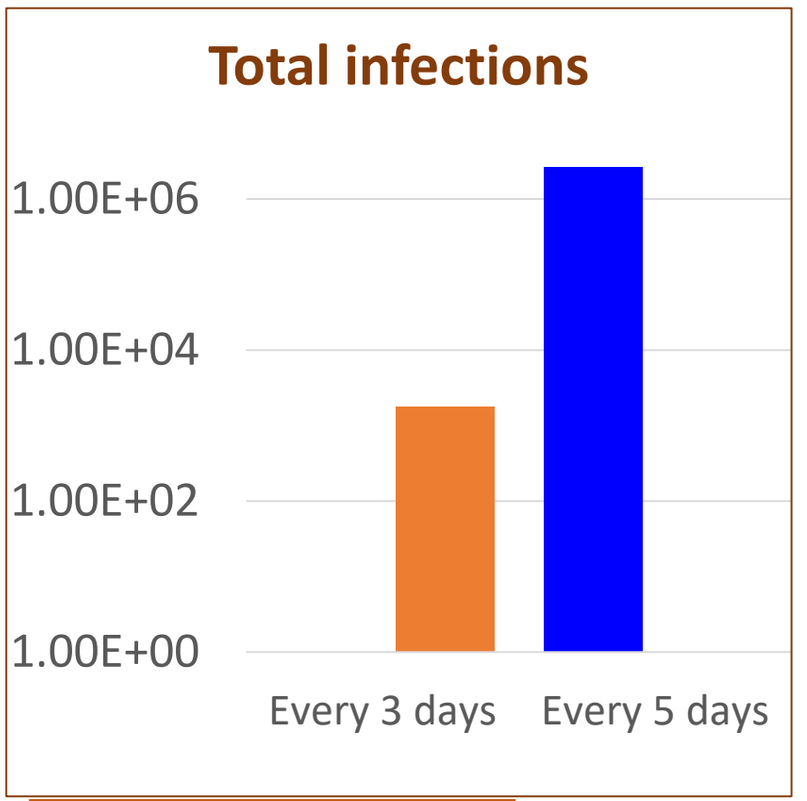
- Range of tests entering market, varying sensitivity/cost: Quantity vs Quality?
  - qRT-PCR ("gold standard"): Detect viral concentration of 10^3/mL, $50-100
  - Antigen strip ("Less sensitive"): 10^6/mL, $3-5

Rapid turnaround time & frequency more critical than sensitivity for COVID-19 surveillance

Less sensitive; Cheap & fast turnaround **More sensitive; Costly & slow turnaround**







COVID Testing Policy: Impact

- Covered in NYT, WaPo, Time, The Atlantic, The Hill, etc
- Allowed epi collaborators to advocate to FDA/CDC


TIME

PERSON OF THE YEAR 2020 FRONTLINE HEALTH WORKERS RACIAL-JUSTICE ORGANIZERS NEWSLETTER

IDEAS • COVID-19

America Needs to Radically Rethink Our COVID-19 Testing Approach


The New York Times

The Coronavirus Outbreak › LIVE Latest Updates Maps and Cases The Latest Vaccine Information The Thanksgiving Effect

'It's Kitchen Sink Time': Fast, Less-Accurate Coronavirus Tests May Be Good Enough


The Atlantic

Popular Latest My Account Give a Gift

The Plan That Could Give Us Our Lives Back

The U.S. has never had enough coronavirus tests. Now a group of epidemiologists, economists, and dreamers is plotting a new strategy to defeat the virus, even before a vaccine is found.

COVID Testing Policy: Impact

The Harvard Gazette

HEALTH & MEDICINE

Approval of at-home tests releases a powerful pandemic-fighting weapon

The Abbott BinaxNOW COVID-19 at-home test was one of two to receive FDA approval this week. The over-the-counter test does not need a prescription.

Courtesy of Abbott

Chan School's Mina says despite vaccination campaign success, diagnostic tools still important

One of them is Michael Mina, assistant professor of epidemiology, who has called on federal regulators for much of the past year to clear the rapid antigen tests, arguing that widespread, frequent use of the diagnostic has the potential to stop outbreaks early and keep case numbers down.

Outline

Public Health

Conservation

- *Protect wildlife, forests, fisheries: Game-focused learning*
- *Integrating real time data for protection: Signaling games*

Protecting Conservation Areas: Green Security Games

(IJCAI 2015)

Fang

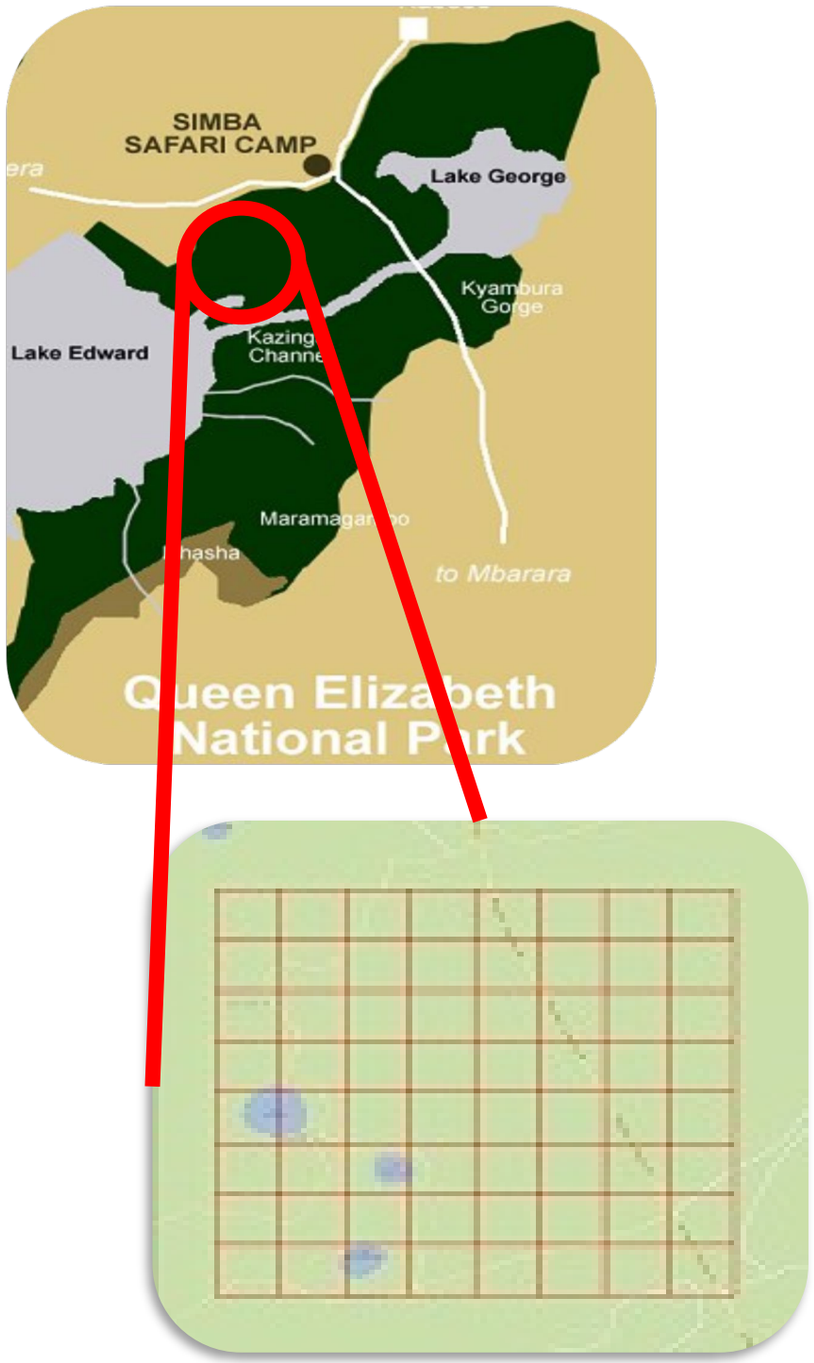
Snare or Trap

Wire snares

Lesson: Step out of the lab & into the field

From Stackelberg Security Games to Green Security Games

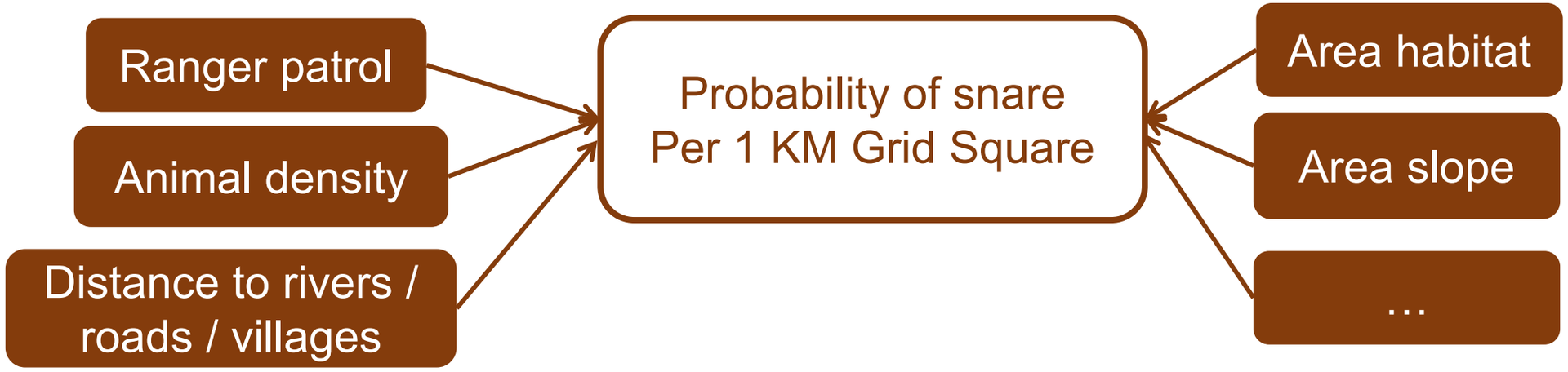
(IJCAI 2015)

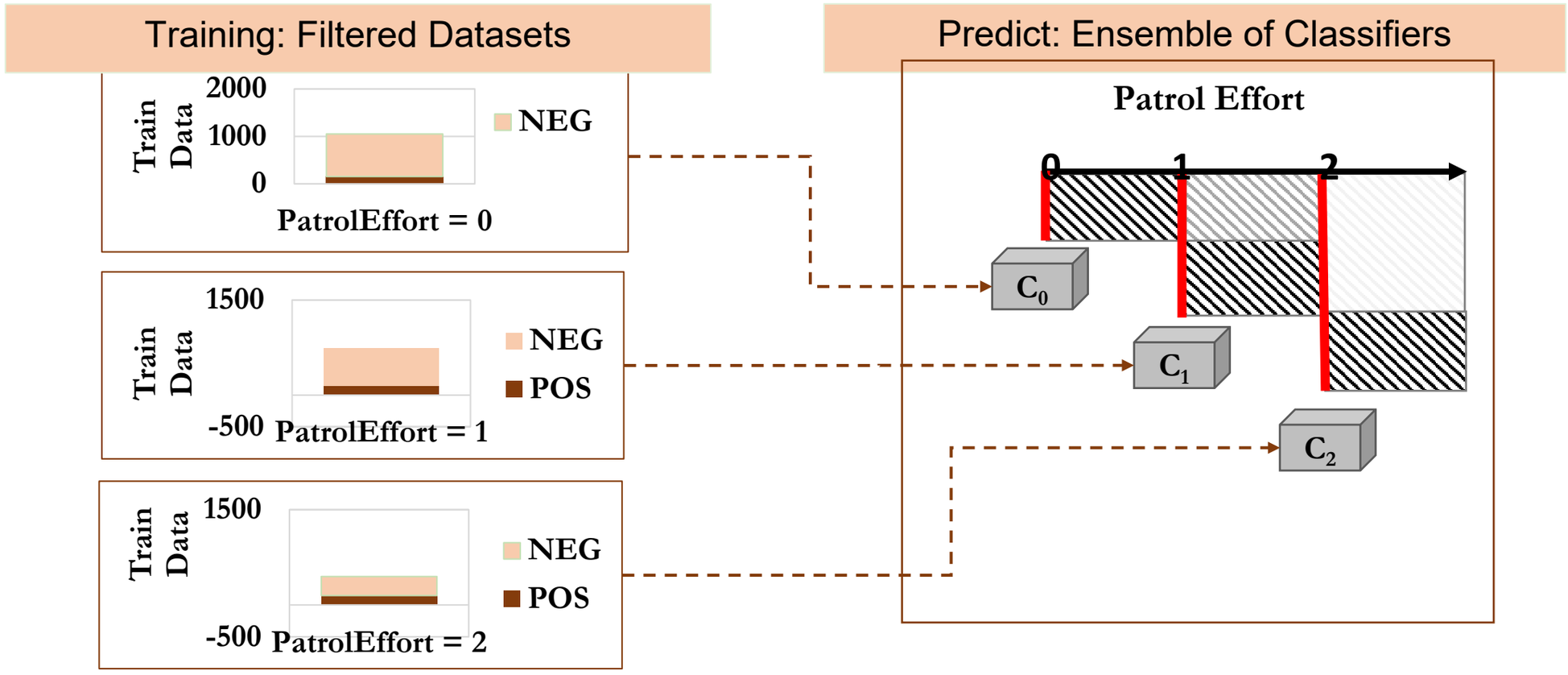


- ***Learn poacher response model at each target***
- ***So can figure out response by patrols***

Learning Adversary Response Model: Uncertainty in Observations


Nguyen Gholami





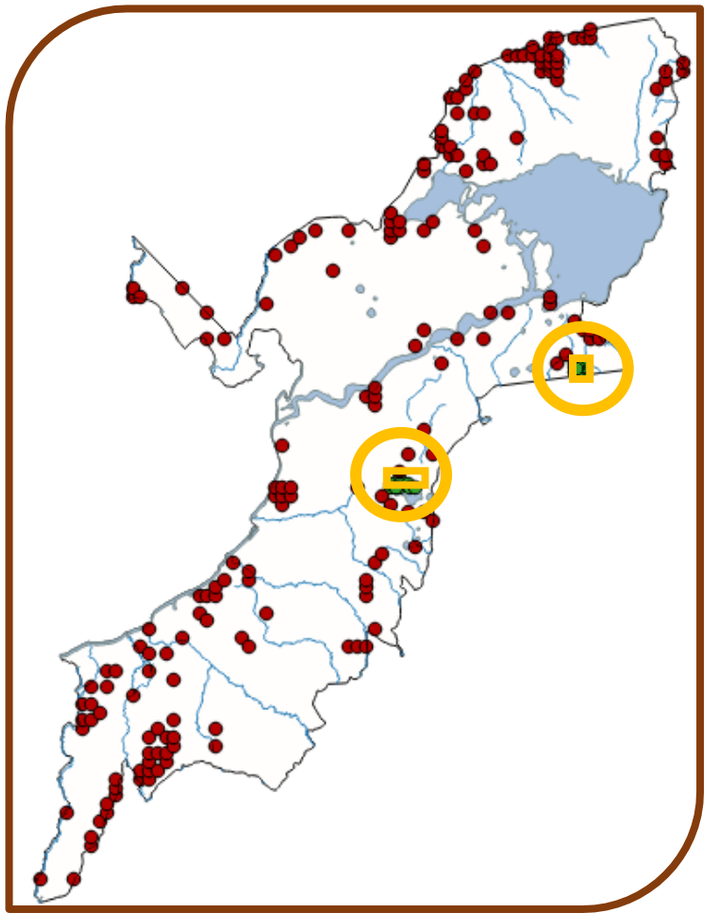
PAWS: First Pilot in the Field

(AAMAS 2017)

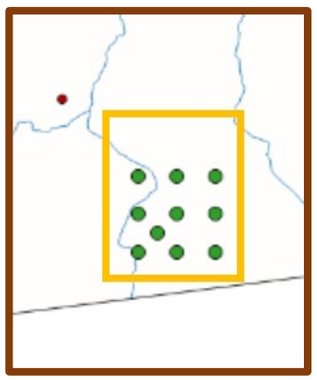
Ford

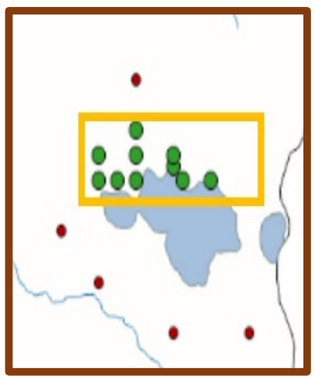
Gholami

- Two 9-sq.km areas, infrequent patrols



- Poached elephant
- 1 elephant snare roll
- 10 Antelope snares



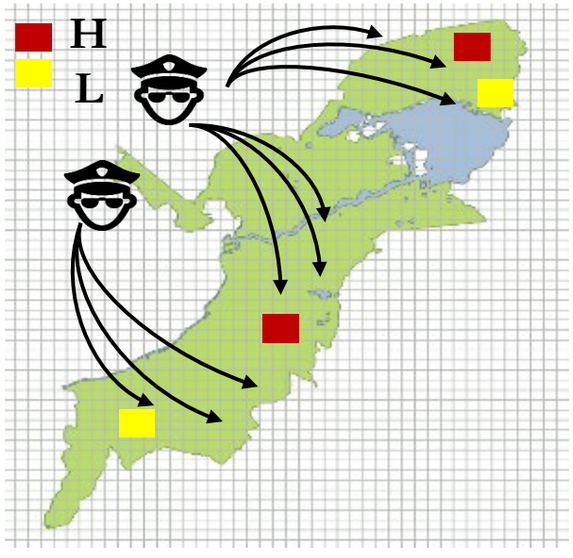


PAWS Predicted High vs Low Risk Areas: 3 National Parks, 24 areas each, 6 months

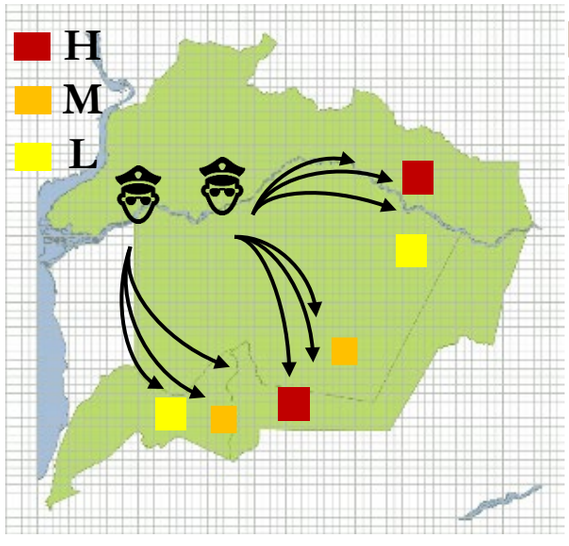
(ECML PKDD 2017, ICDE 2020)

Xu

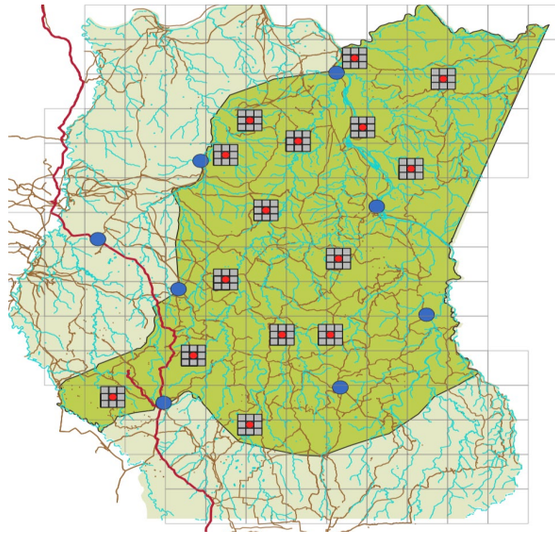
Gholami



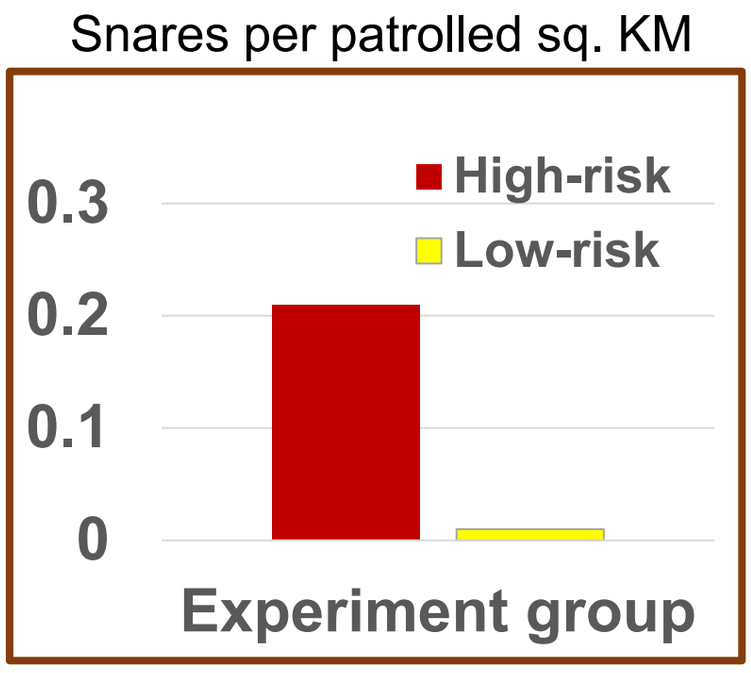
Queen Elizabeth National Park

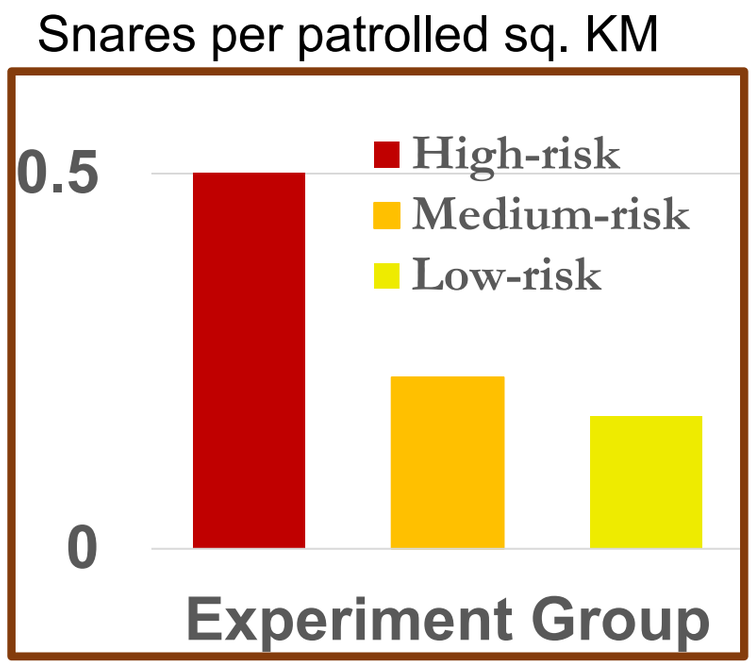


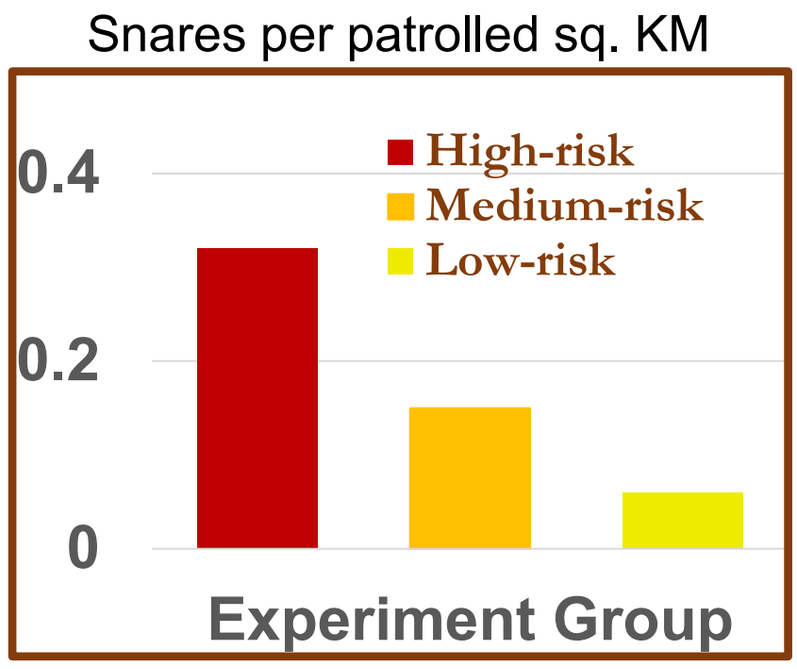
Murchison Falls National Park



Srepok Wildlife Sanctuary







PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary
(ICDE 2020)


Xu

2019 PAWS: *521 snares/month*

vs

2018: *101 snares/month*

2021 PAWS

1,000 snares found in March

PAWS GOES GLOBAL with SMART platform!!

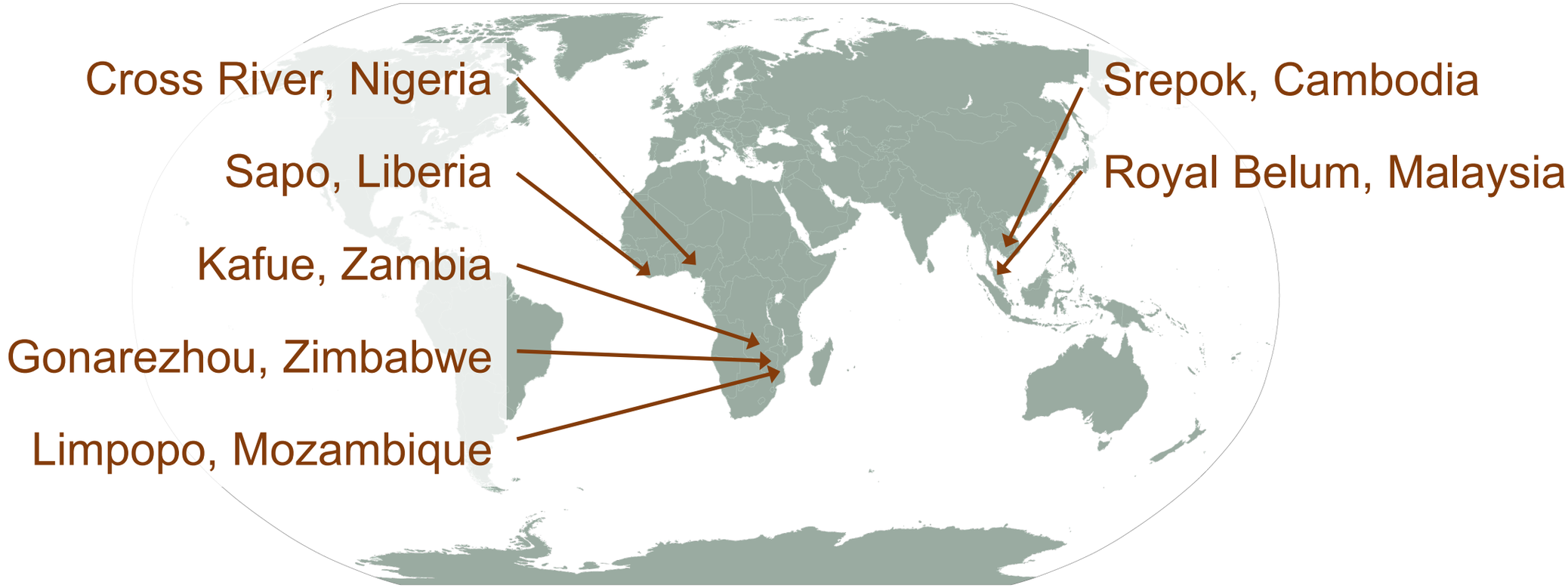
SMART

WWF

PEACE PARKS FOUNDATION · THE GLOBAL SOLUTION ·

WCS

Protect Wildlife
800 National Parks
Around the Globe

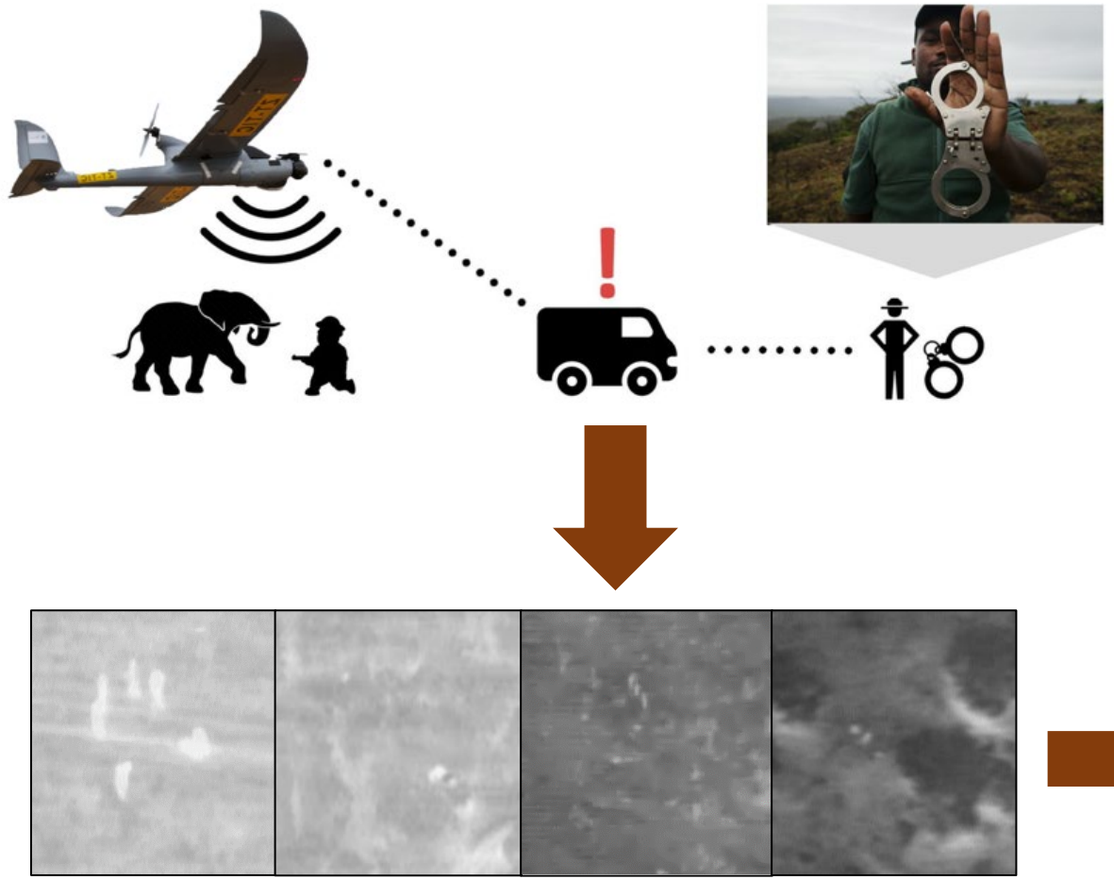


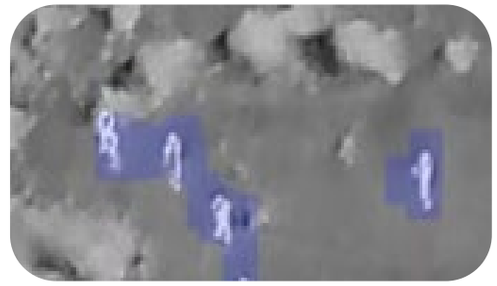
Direction #1:
Integrating Real-Time “SPOT” Information

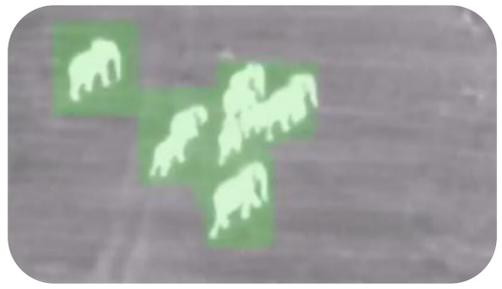
(IAAI 2018)

Bondi

Air Shepherd
The Lindbergh Foundation







Goal: automatically find poachers

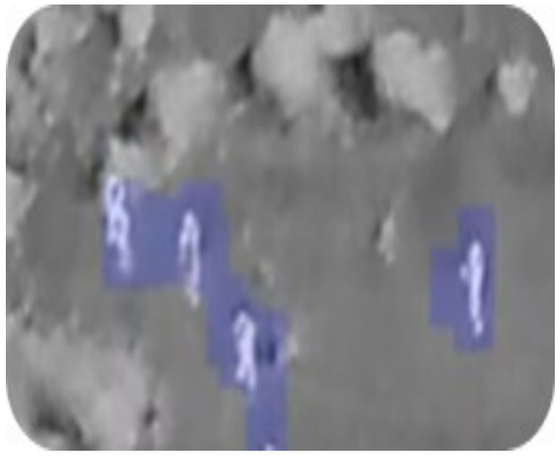
Drone Used to Inform Rangers


Xu


Bondi

- *Prob(ranger arrives)* = 0.3 [poacher may not be stopped]
- Deceptive signaling to indicate ranger is arriving

Air Shepherd
The Lindbergh Foundation



Prob(ranger) = 0.3

Drone Used to Inform Rangers


Xu


Bondi

- *Prob(ranger arrives)* = 0.3 [poacher may not be stopped]
- Deceptive signaling to indicate ranger is arriving

Air Shepherd
The Lindbergh Foundation

Prob(ranger) = 0.3

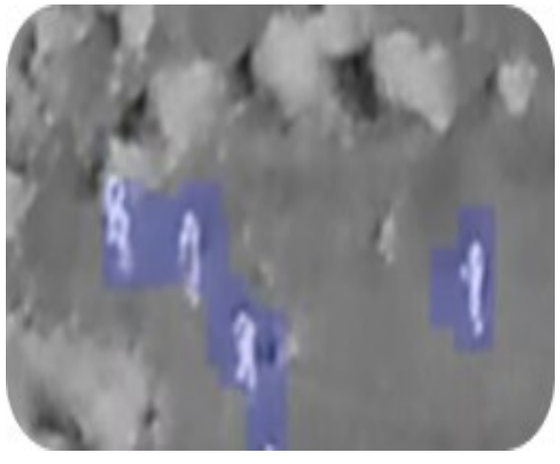
Drone Used to Inform Rangers


Xu


Bondi

- *Prob(ranger arrives)* = 0.3 [poacher may not be stopped]
- Deceptive signaling to indicate ranger is arriving
- Must be strategic in deceptive signaling

Air Shepherd
The Lindbergh Foundation



Prob(ranger) = 0.3

Exploiting Informational Advantage
Defender Knows Pure & Mixed Strategy

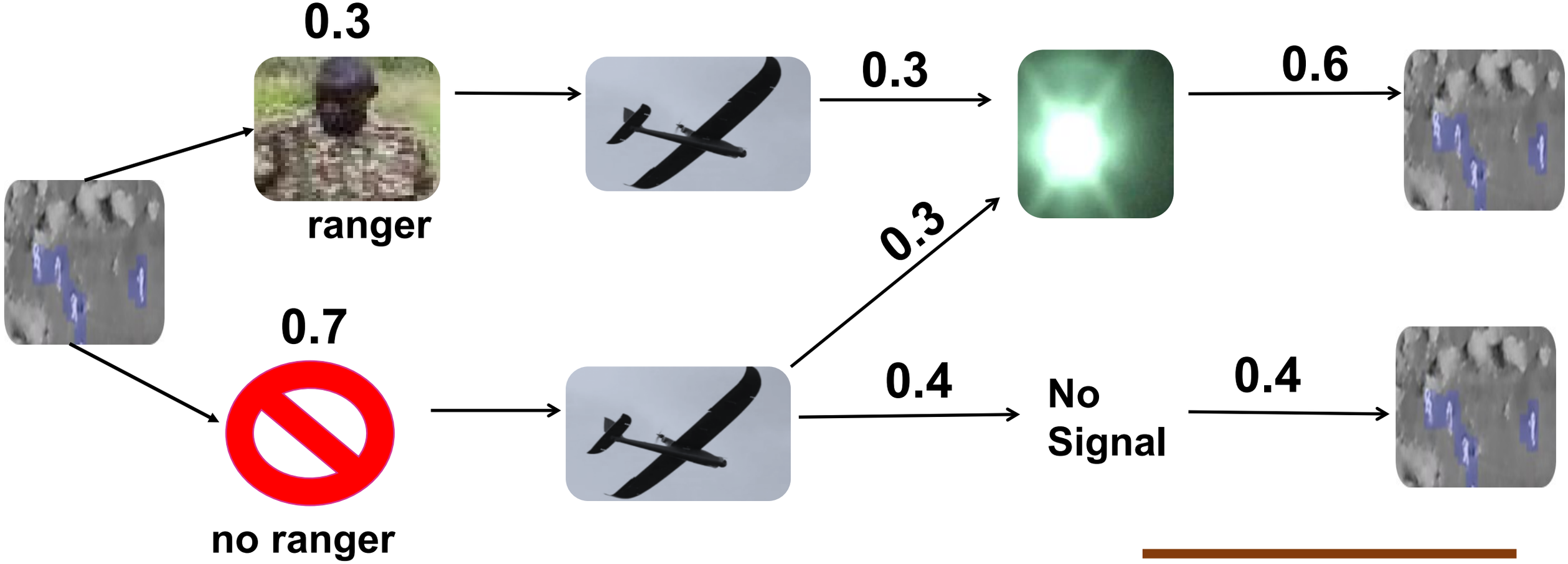
(AAAI 2018, AAAI 2020, AAMAS 2021)

Xu

Bondi

Si-G Model: Stackelberg Security Games with Optimal Deceptive Signaling

- Poacher best interest to “believe signal” even if know 50% defender deception
- Recent work used RL for deception policy generation (AAMAS 2021)



Future: AI for Social Impact (AI4SG or AI4SI)

Achieving social impact & AI innovation go hand in hand

Empower non-profits to use AI tools; avoid being gatekeepers to AI4SI tech

Data to deployment: Not just improving algorithms, new AI4SI evaluation

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

Key Collaborators on Papers Referenced

(In the order papers referenced)

- Eric Rice (USC)
- Nicole Immorlica (MSR)
- Yair Zick (UMASS, Amherst)
- Balaraman Ravindran (IIT-Madras)
- Amit Sharma (MSR)
- Maia Majumder (Harvard)
- Michael Mina (Harvard)
- Daniel Larremore (Colorado)
- Andy Plumptre (Cambridge)
- Rohit Singh (WWF)
- Phebe Vayanos (USC)
- Bistra Dilkina (USC)

@MilindTambe_AI

Collaborate to realize AI's tremendous potential to Improving society & fighting social injustice