How to "AI for Social Good": Case Studies in applying AI for Public Health & Conservation

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AI and Multiagent Systems Research for Social Impact

Public Health

Conservation

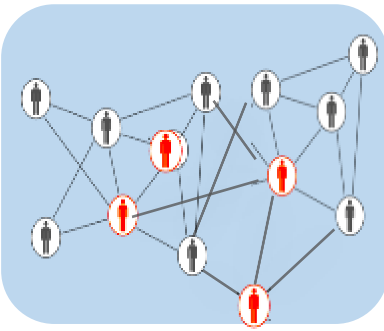
Public Safety and Security

Viewing Social Problems as Multiagent Systems

Key research challenge across problem areas:

Optimize Our Limited Intervention Resources
when
Interacting with Other Agents

Optimizing Limited Intervention Resources



Social Networks & Bandits

Public Health

Green security games

Conservation

Public Safety & Security

Stackelberg security games

Google Research Bangalore
AI for Social Good

armman
Delivering India's Future

KhushiBaby

Swasti
THE HEALTH CATALYST

Public Health

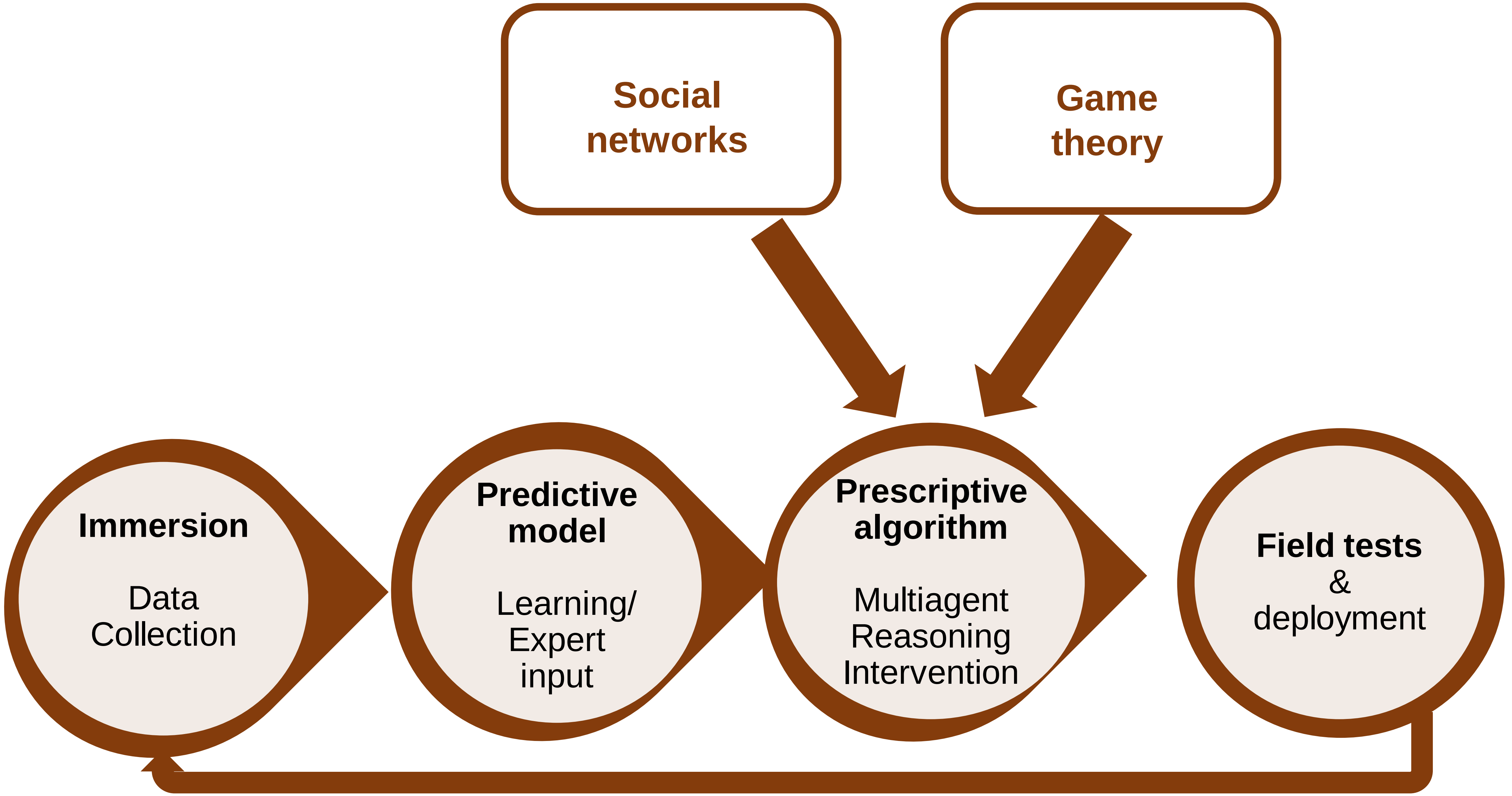
atree
ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT

Wildlife Conservation Trust

Conservation

Three Common Themes

Multiagent systems, Data-to-deployment pipeline, Interdisciplinary partnerships

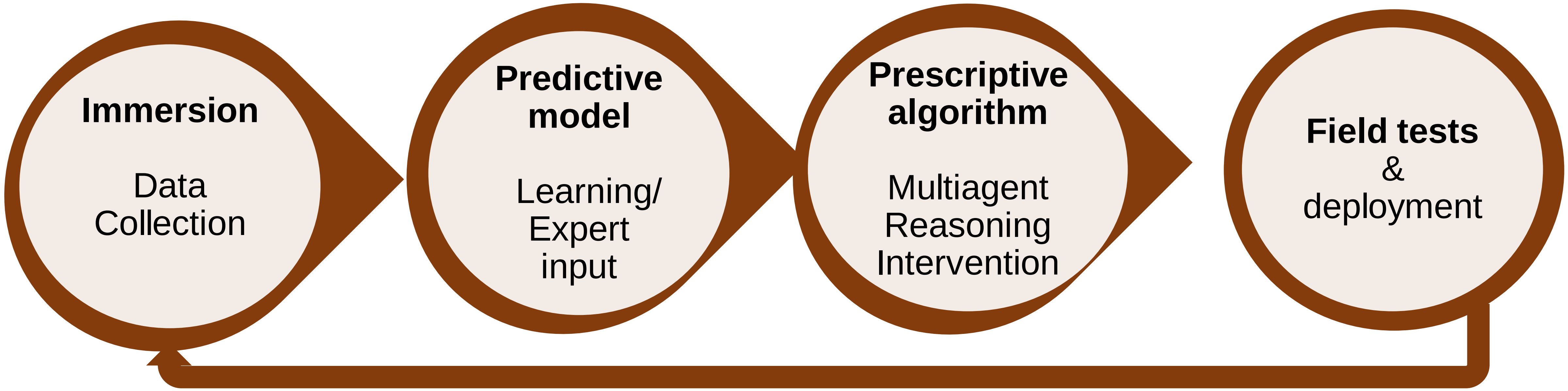


Three Common Themes

Multiagent systems, Data-to-deployment pipeline, Interdisciplinary partnerships

Field test & deployment: Social impact is a key objective

Lack of data is a norm: Must be part of project strategy



Three Common Themes

Multiagent systems, Data-to-deployment pipeline, Interdisciplinary partnerships

LOS ANGELES LGBT CENTER

S.P.Y safe place for youth

my friend's place

armman

ASHOKA TRUST FOR RESEARCH IN ECOLOGY & THE ENVIRONMENT (atree)

Wildlife Conservation Society

WWF

Wildlife Conservation Trust

SMART

Air Shepherd The Lindbergh Foundation

Swasti THE HEALTH CATALYST

everwell

KhushiBaby

PRATHAM BOOKS

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

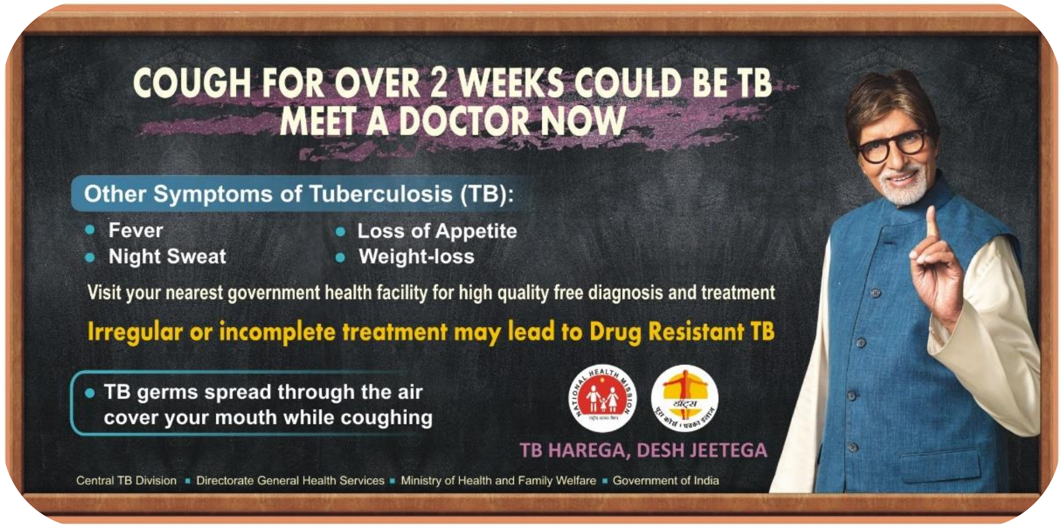
Transportation Security Administration

Three Key Takeaways: AI4SG

What are key problem types for AI for Social Good in public health & conservation?

What are some key AI research challenges (pay attention to models, not details)

How do we launch projects in AI for Social Good?



Outline

Public Health

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

Conservation

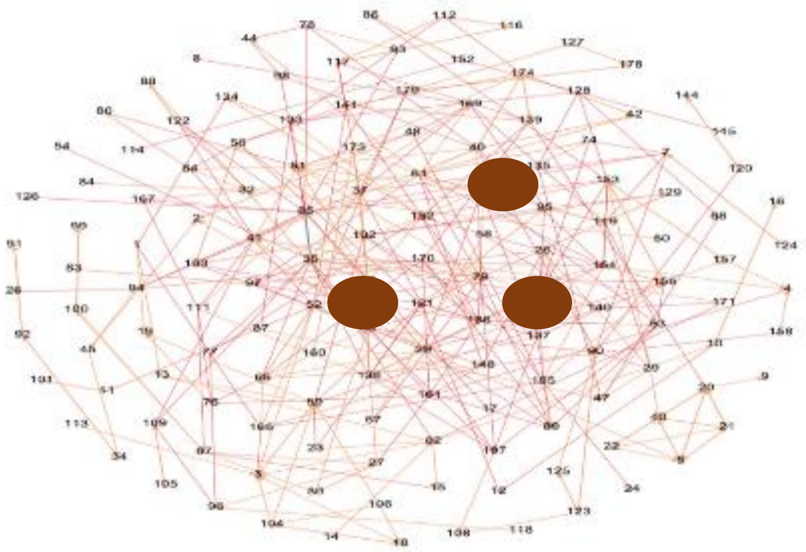
- Cover papers from 2017-now [AAMAS, AAAI, IJCAI, NeurIPS…]
- PhD students & postdocs highlighted

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

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" face-to-face interactions; not Facebook etc*
- *Other applications: HIV prevention (SWASTI), Tuberculosis awareness…*

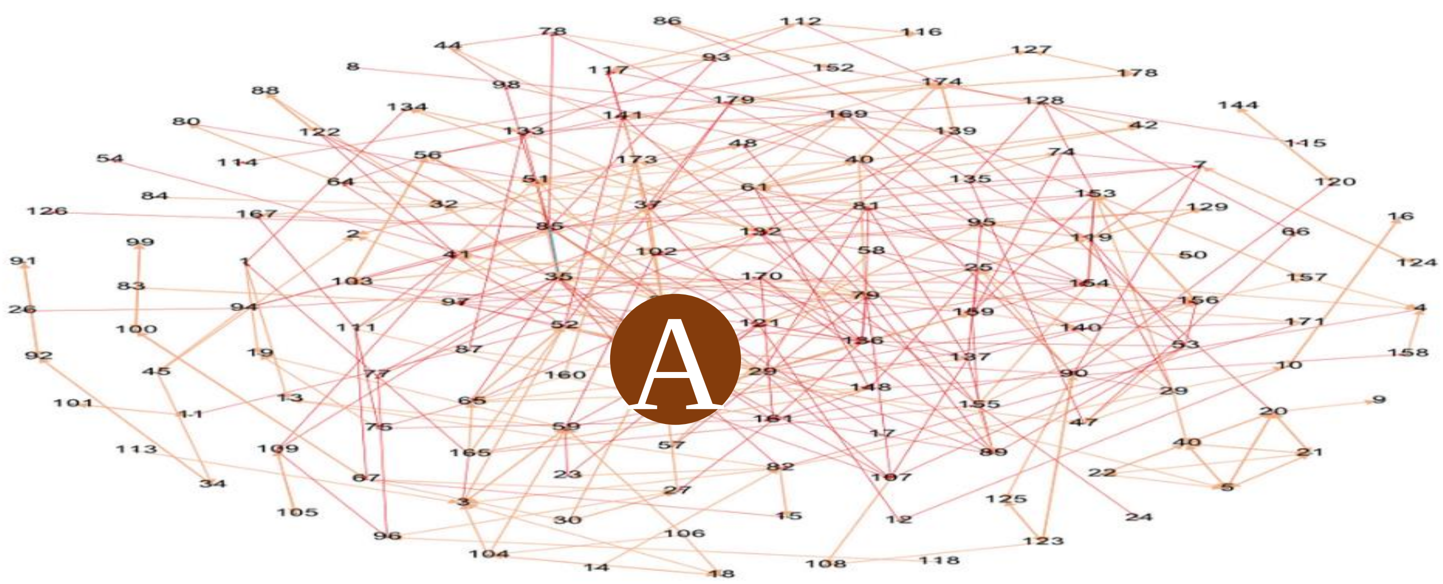
Influence Maximization in Social Networks



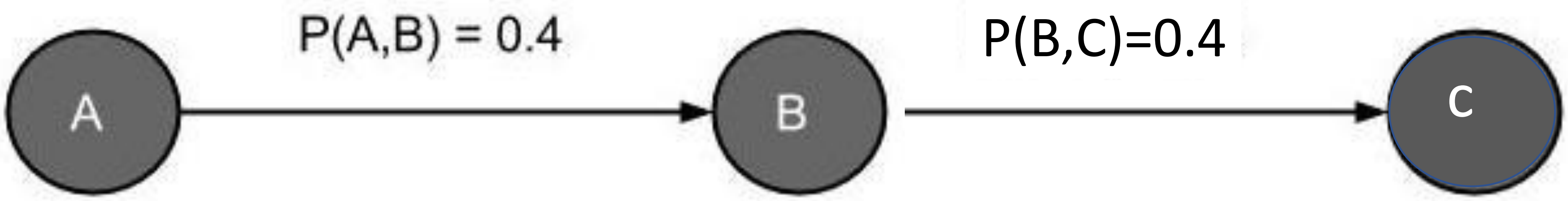
- Given:
  - Social network Graph G
  - Choose K “peer leader” or influencer nodes
  - Assume: Independent cascade model of information spread

- Objective:
  - Maximize expected number of influenced nodes

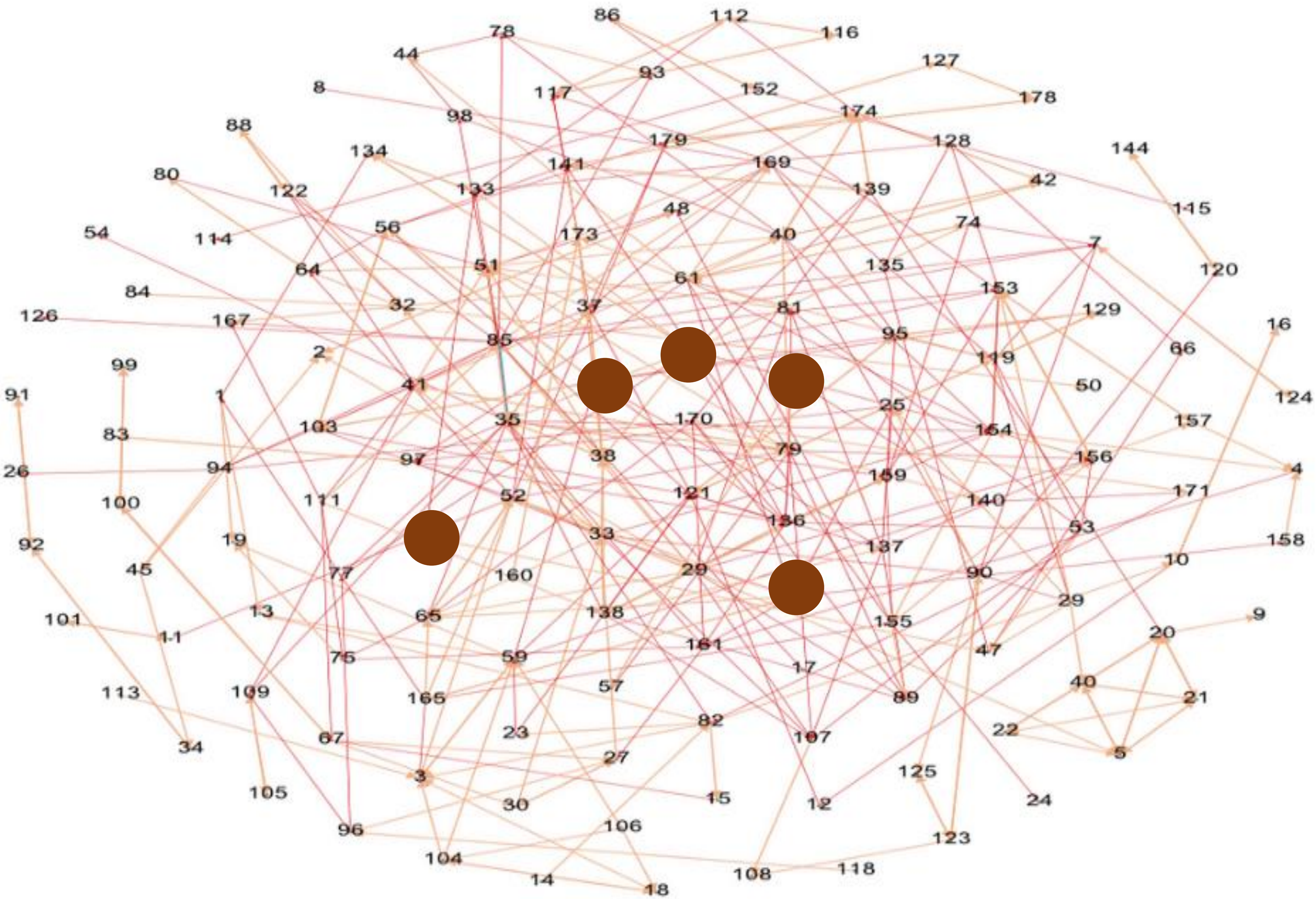
Independent Cascade Model



- Propagation Probability (for each edge)



Influence Maximization (Budget = 5 nodes)




PEER LEADERS
OUR MISSION
SEXUAL HEALTH
HIV 101
COMMUNICATION
LEADERSHIP
SELF-CARE
Facts
HIV is a virus
EMPIRE
STATE

Influence Maximization in Social Networks
Three Key Challenges Combined Together

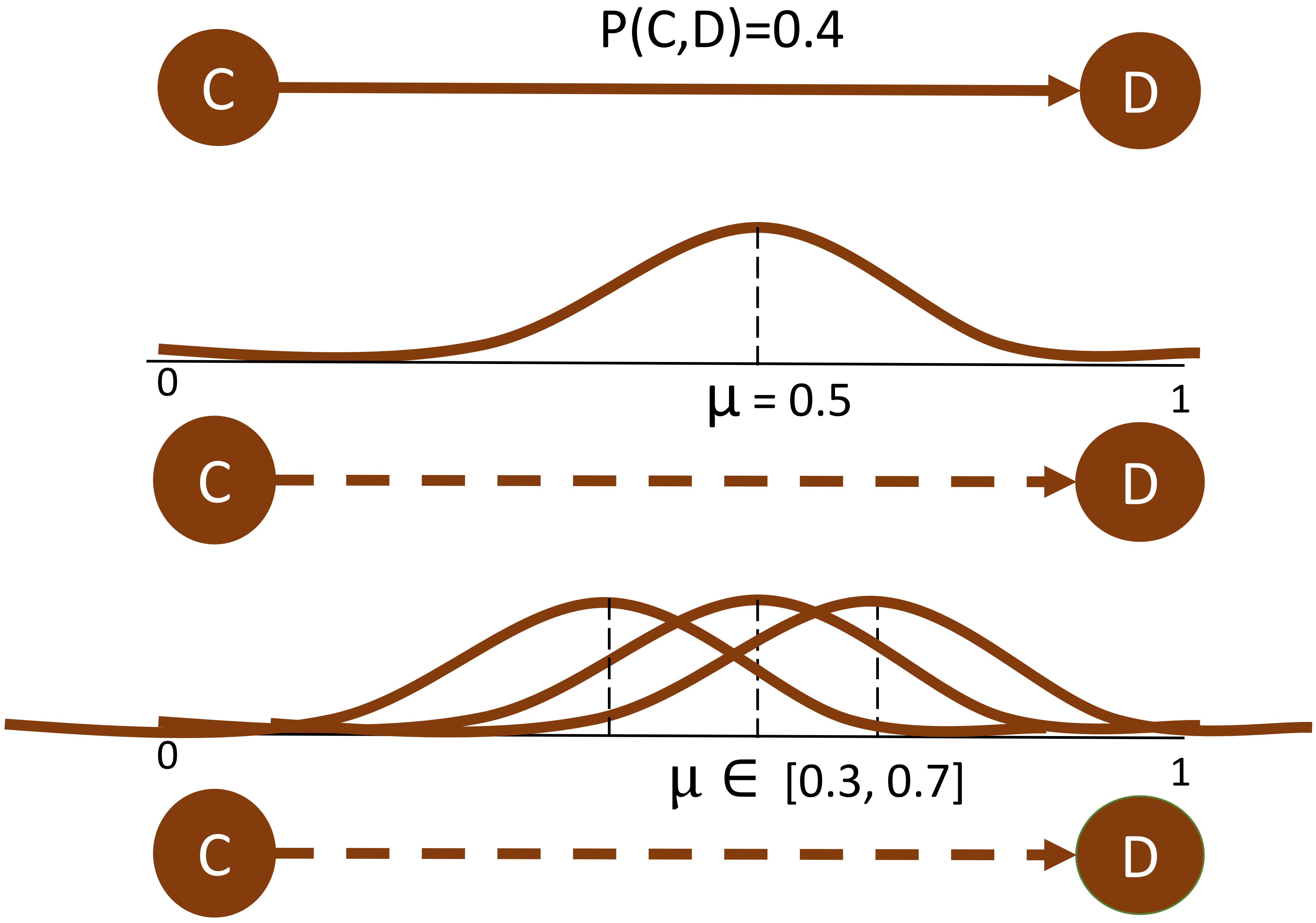
Research challenges in AI for social good?

Lack of data & uncertainty is a feature (research challenge), not a bug

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

Focus on the key idea; mathematical details read papers later

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

Theorem: Converge with approximation guarantees

- Equilibrium strategy despite exponential strategy spaces: 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

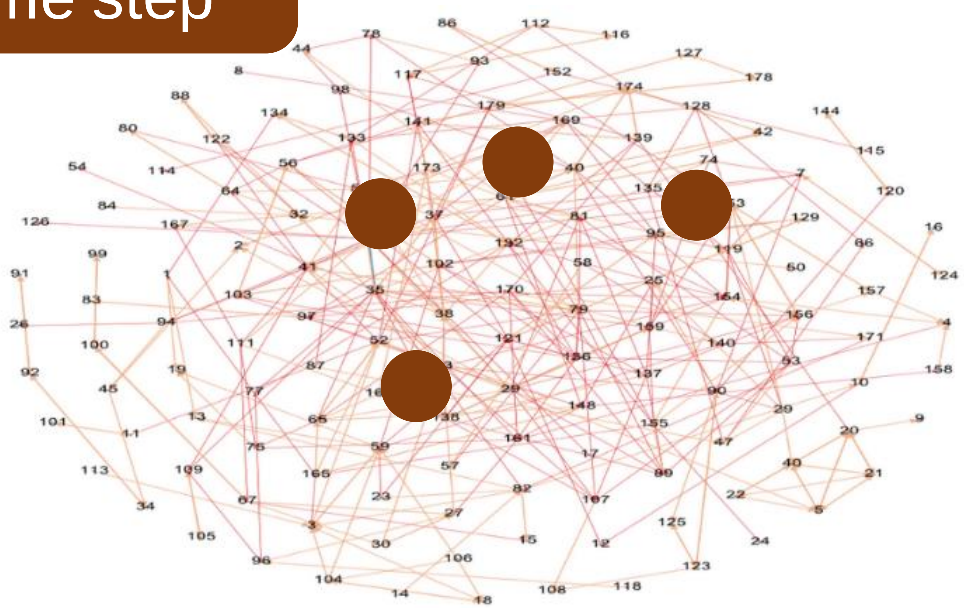
	Params #1	Params #2	Params #3
Policy #1	0.8, -0.8	0.3, -0.3	0.4, -0.4
Policy #2	0.7, -0.7	0.5, -0.5	0.6, -0.6
Policy #3	0.6, -0.6	0.4, -0.4	0.7, -0.7

Challenge 2: Multi-step Policy

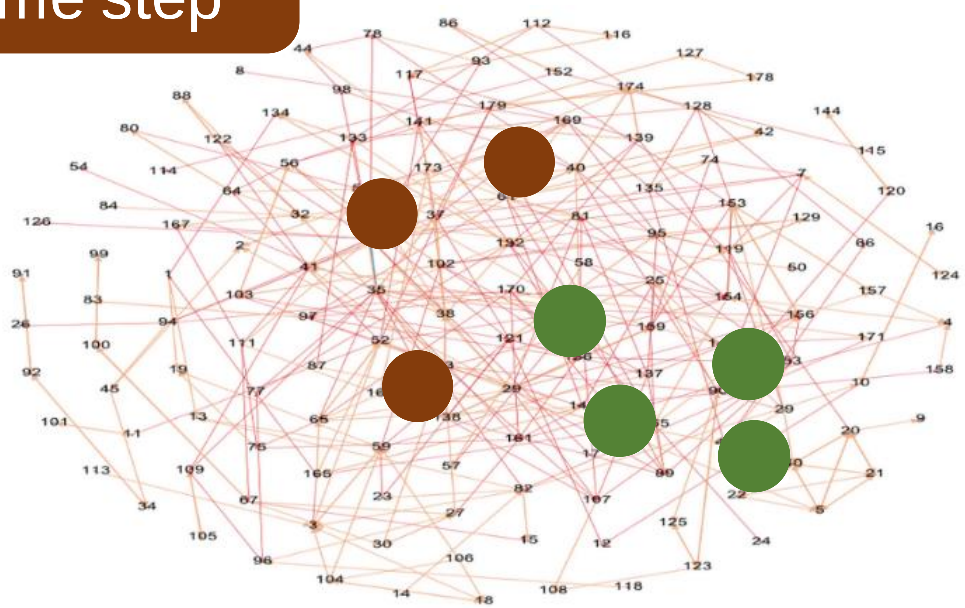

Yadav


Wilder

K = 4
1st time step



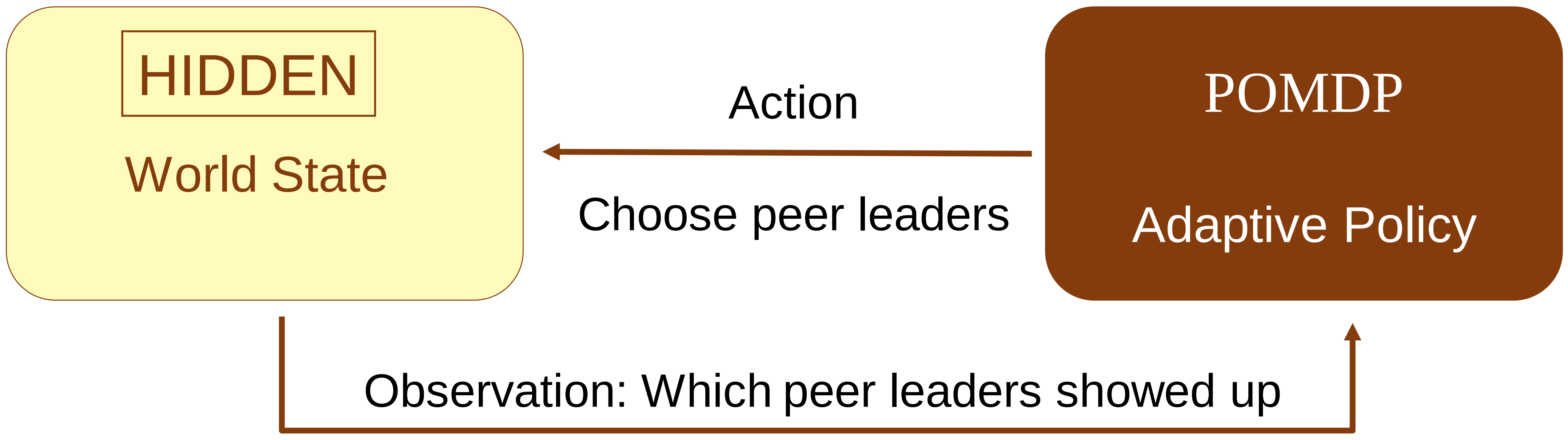
K = 4
2nd time step



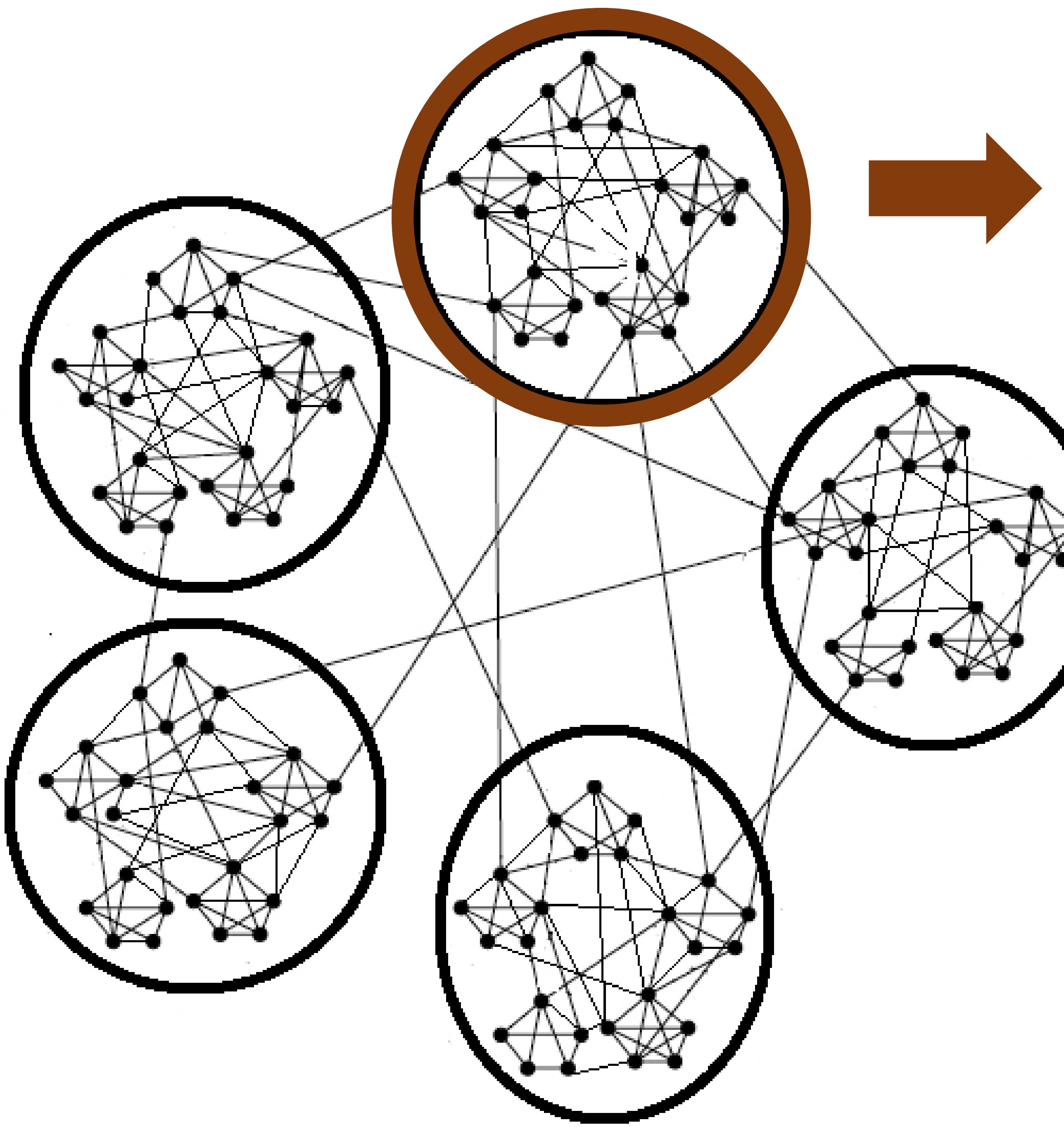
- History: *{(Invited-at-time1, absent-at-time1), (Invited-at-time2, absent-at-time2),…}*
- Provide policy *p: History(t) → Invite peer leaders for t+1*
- State of network is unobservable

POMDP (Partially Observable Markov Decision Problem)

- Sequential decision making under uncertainty
  - Homeless shelters – sequentially select nodes
- Environment state not fully observable to agent
  - Homeless shelters – network state not known

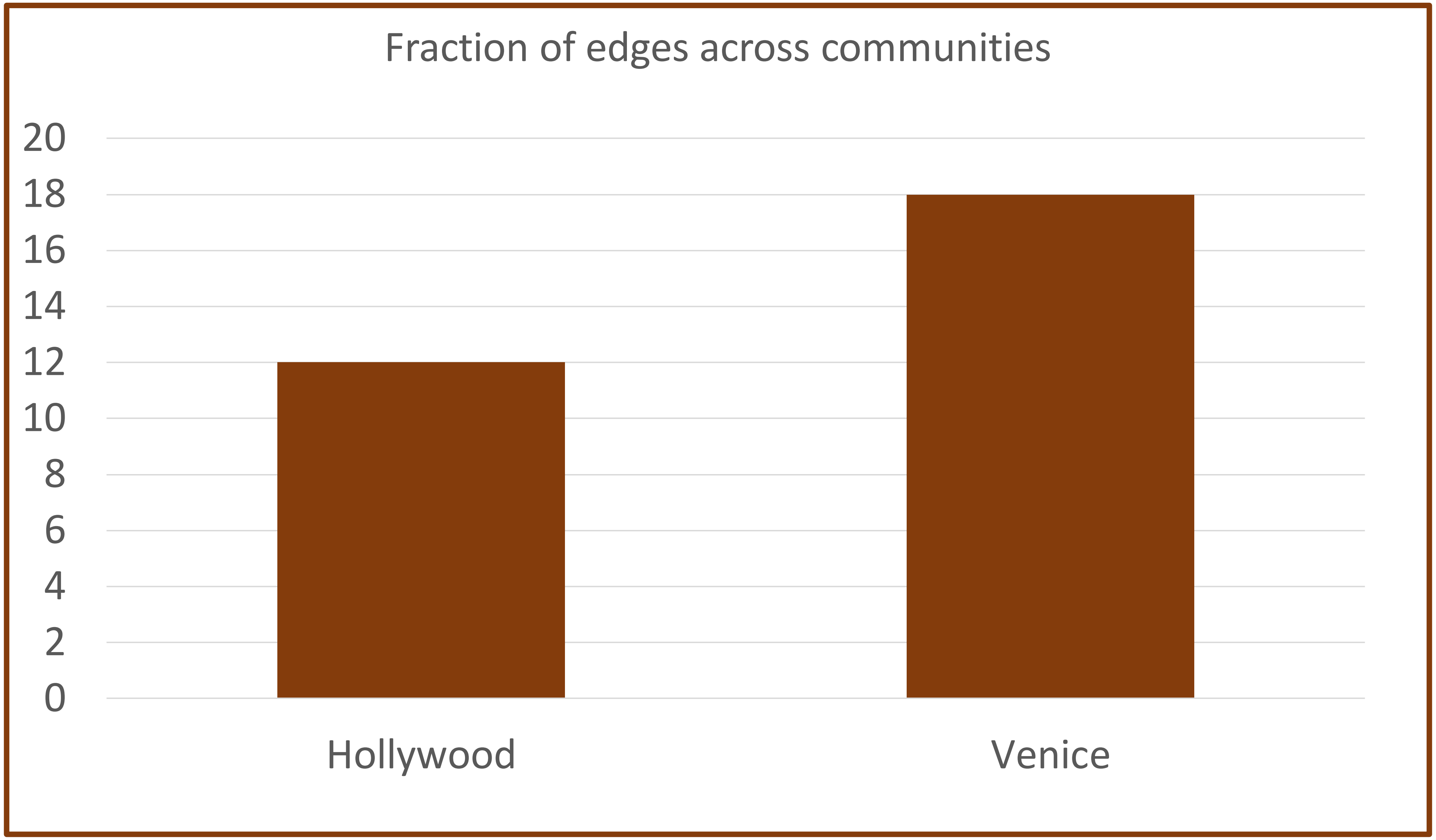


Graph Partitioning: POMDPs Expensive to Solve



Real world networks have community structure

Graph Partitioning



POMDPs for Multi-Step Policy for Robust, Dynamic Influence Maximization

(AAMAS 2018a)

Yadav

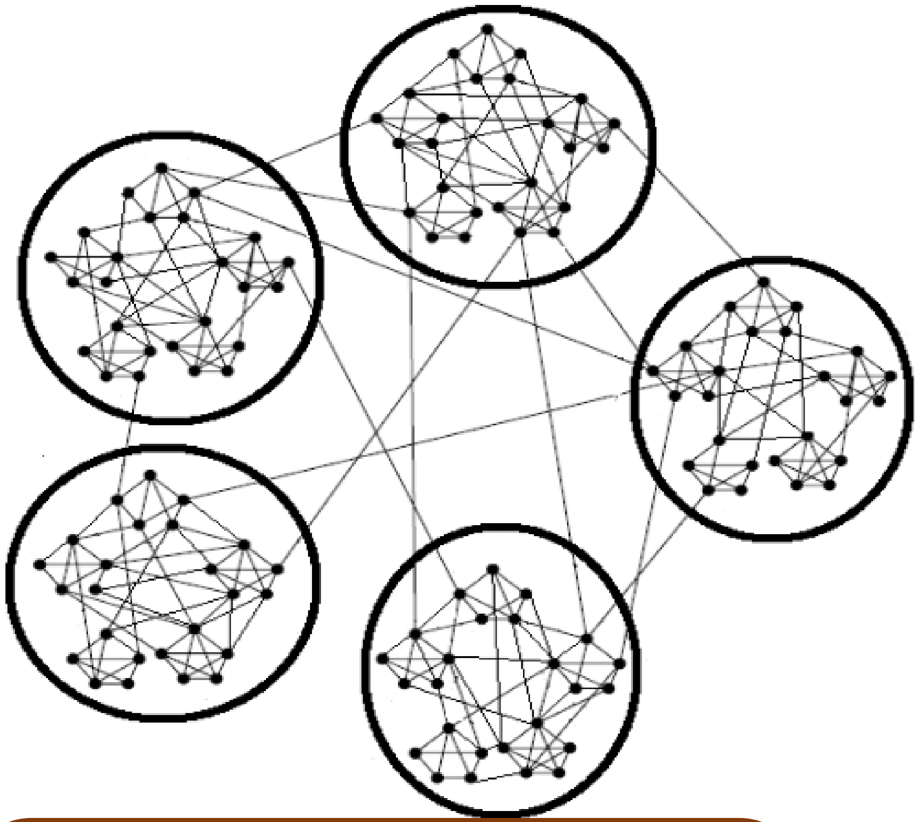
HIDDEN STATE

Action

Choose nodes

POMDP Policy

Observation: Node presence



Adaptive Policy

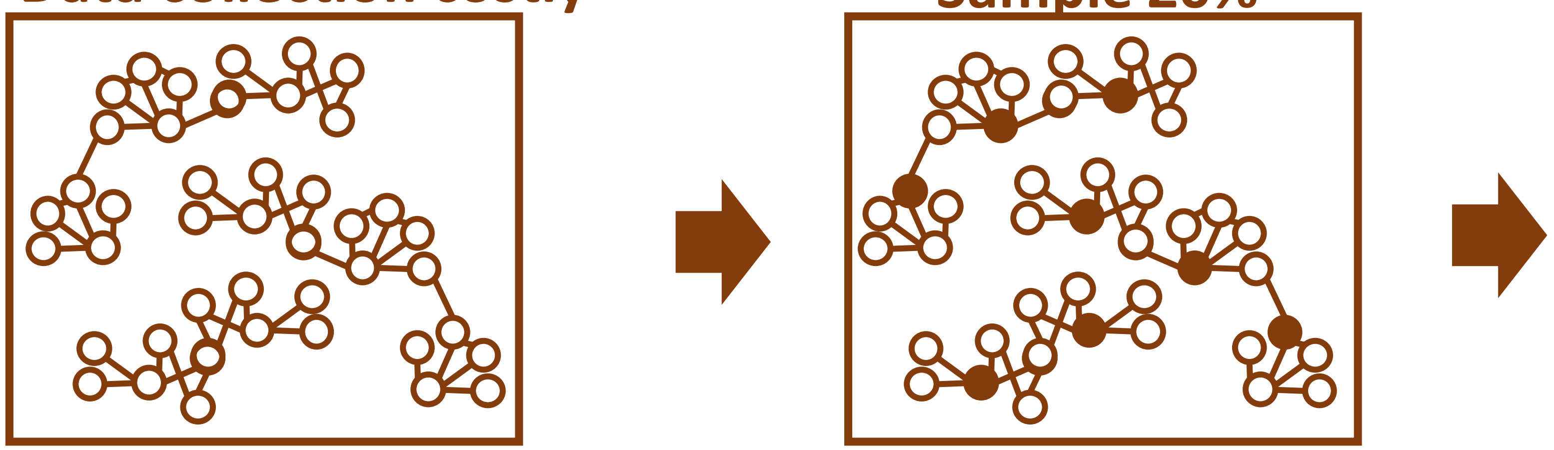
Partition POMDPs: Exploit community structure

Challenge 3:
Sampling to avoid Data Collection Bottleneck
(AAAI 2018)

Wilder

Theorem: For community-structured graphs(*), sampling algorithm obtains a constant-factor approximation to the optimal influence spread using polylog(n) queries.

Data collection costly **Sample 20%**



Sampling Algorithm

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

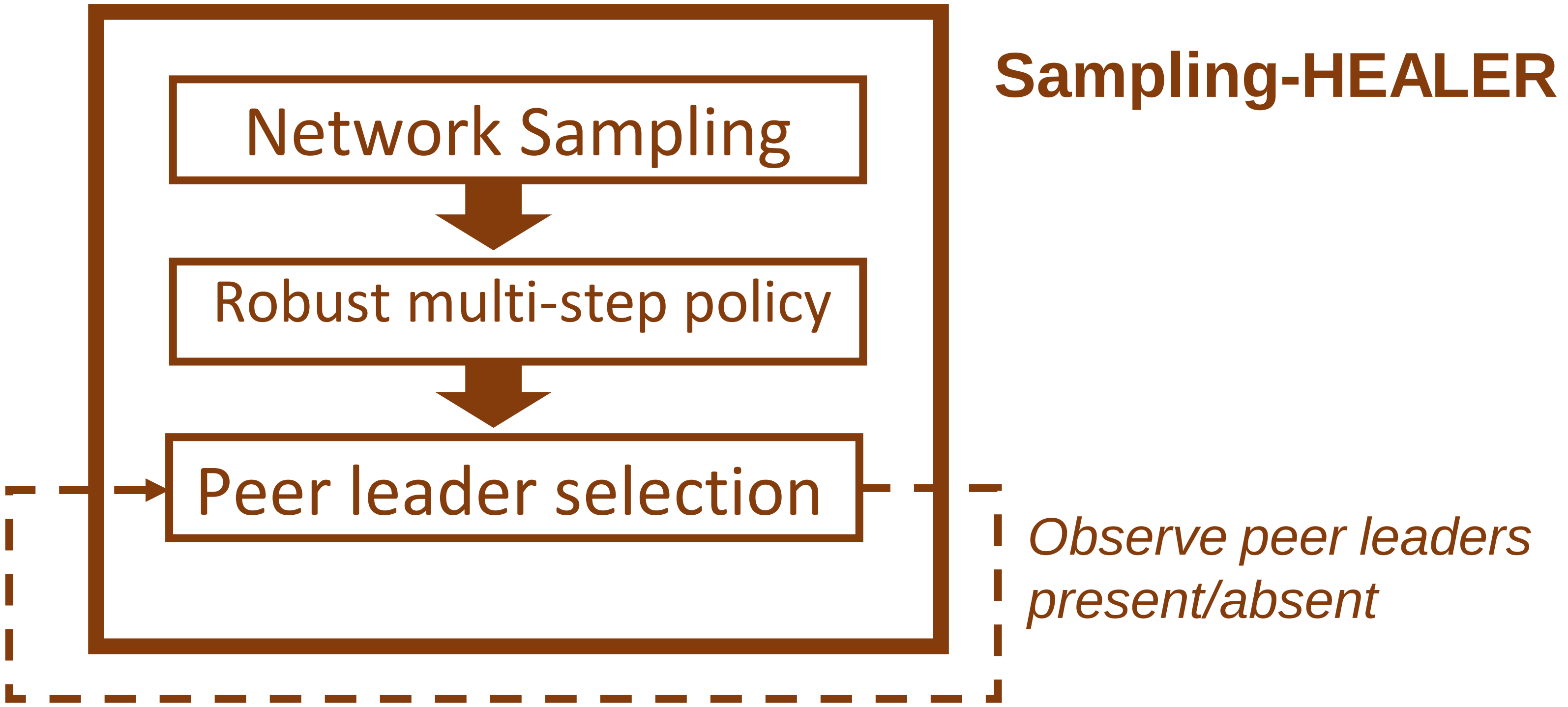
- Input: total number of nodes, n
- Sampling algorithm queries upto query budget
- Output K seed nodes; spread influence via independent cascade model
- Compare to OPT, best influence spread by algorithm with full network

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

“Sampling-HEALER”
Pilot tests with 230 Homeless Youth
(IJCAI 2018)

Yadav

Wilder



12 peer leaders

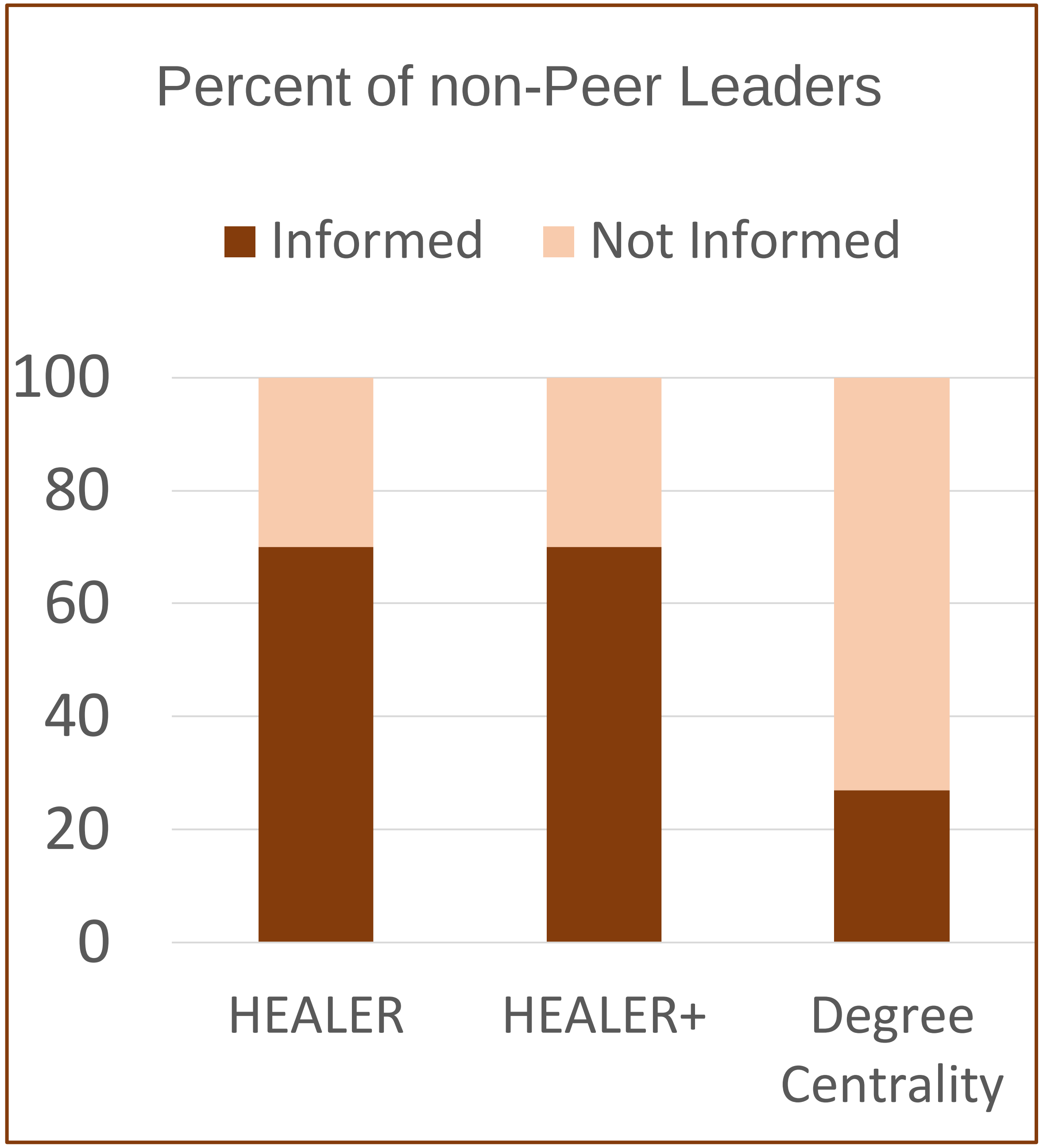
Sampling HEALER (Sampled Network)	HEALER (Full Network)	HEALER+ (Full Network)	DEGREE CENTRALITY (Full Network)
60 youth	62 youth	56 youth	55 youth

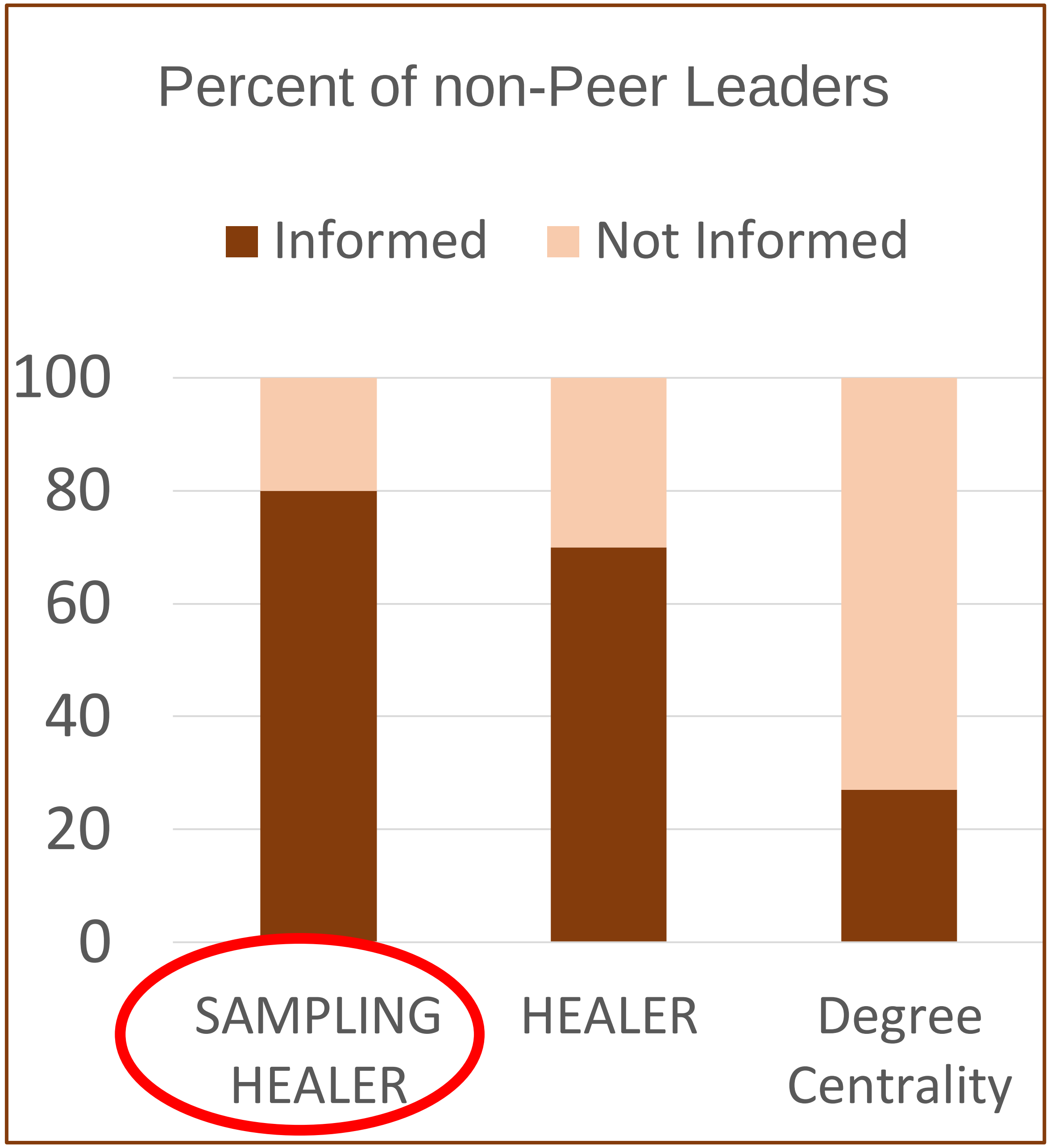
Results: Pilot Studies

(Journal of Society of Social Work & Research 2018)


Yadav

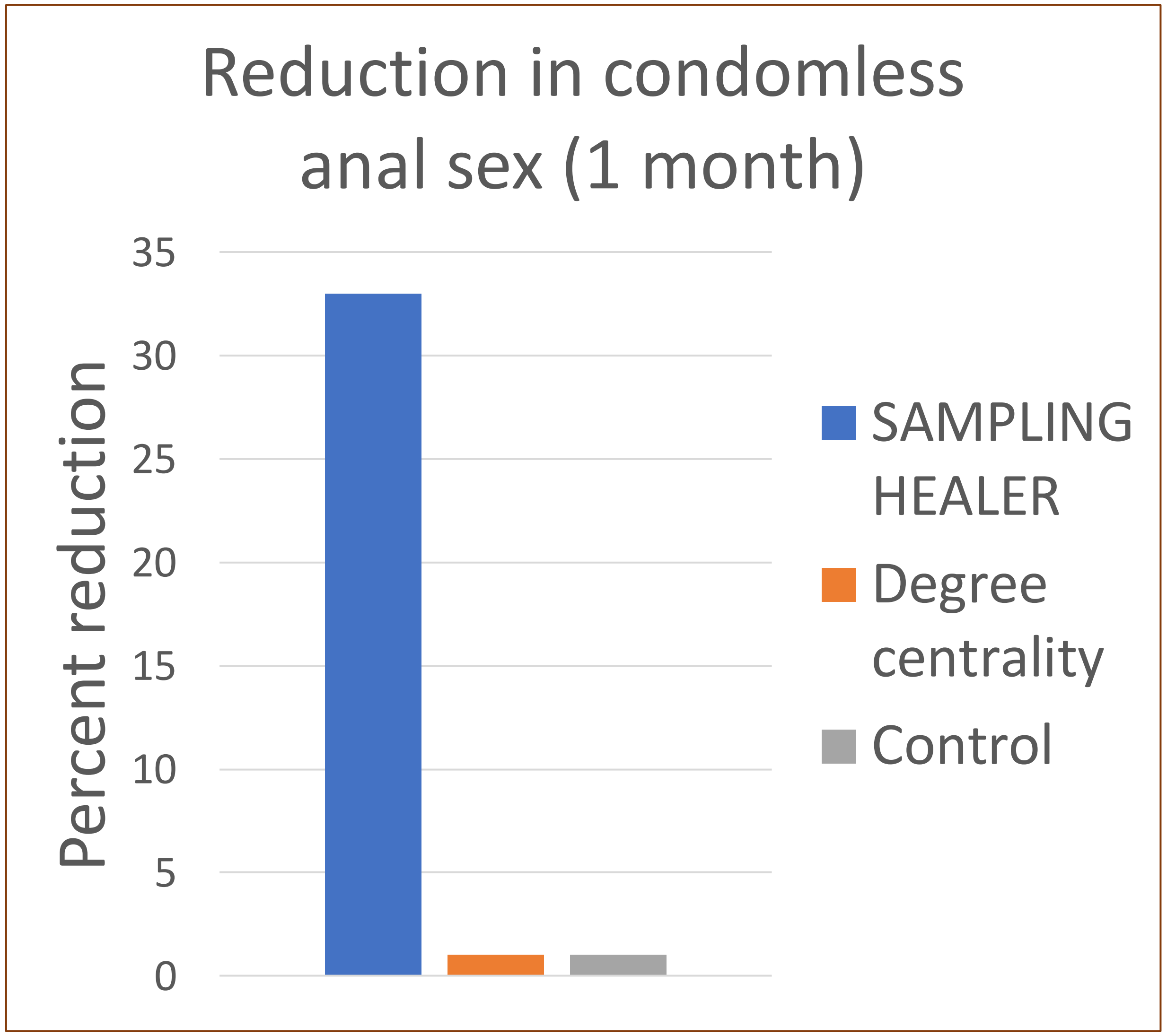

Wilder

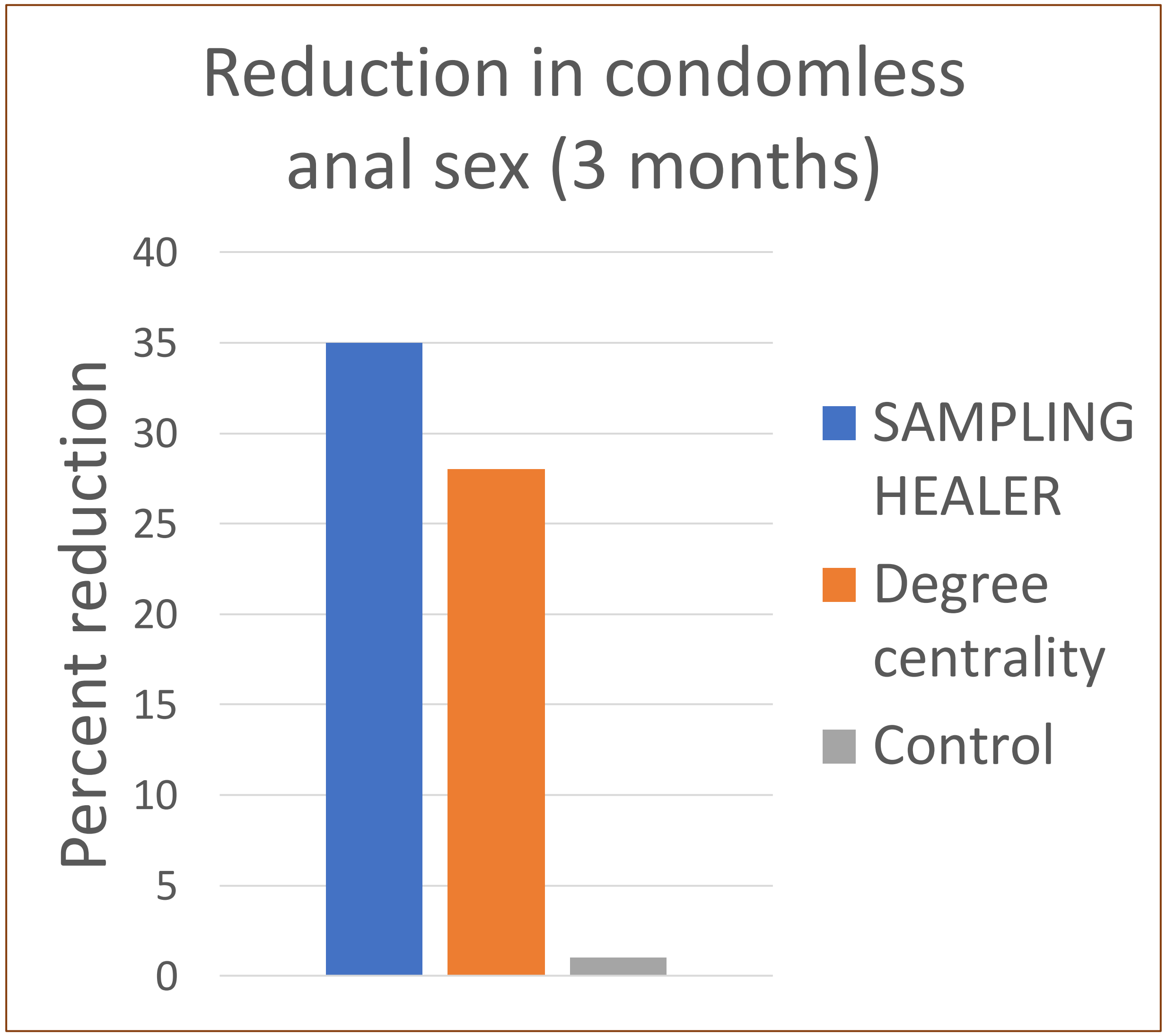




Results of 800 Youth Study [with Prof. Eric Rice]
Actual Change in Behavior?
(Under submission)

First large-scale application of influence maximization for public health





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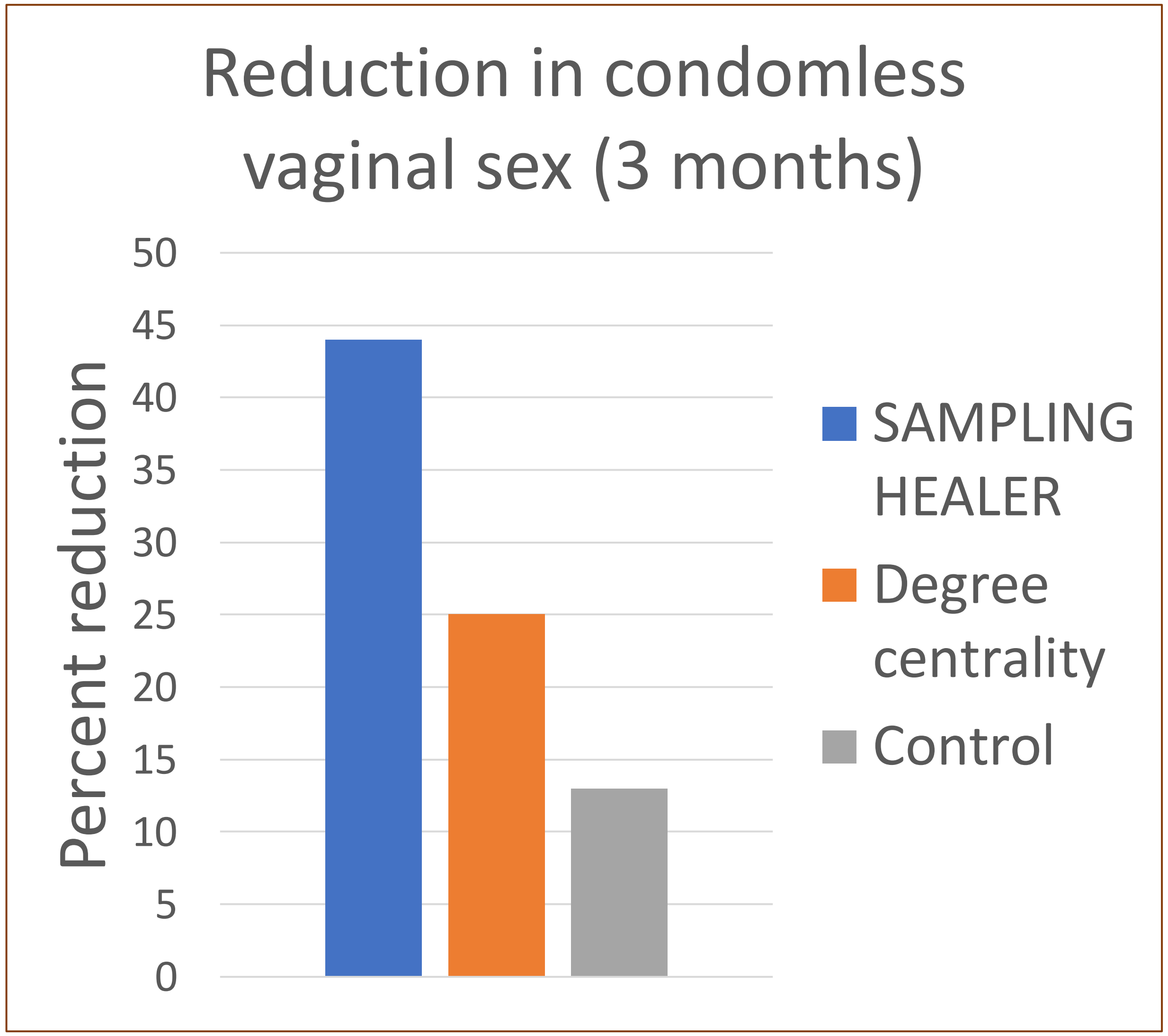
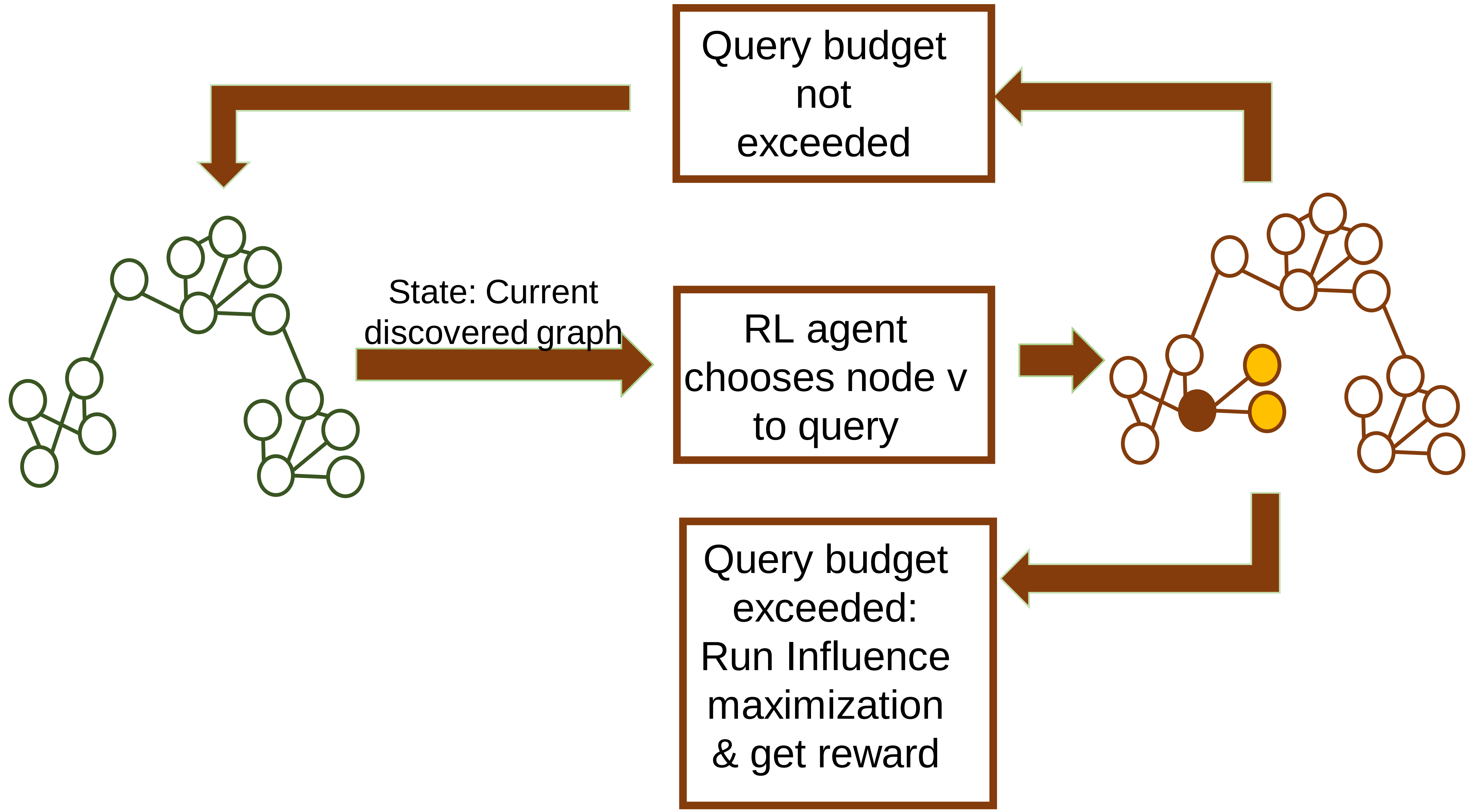


AI Assistant: HEALER

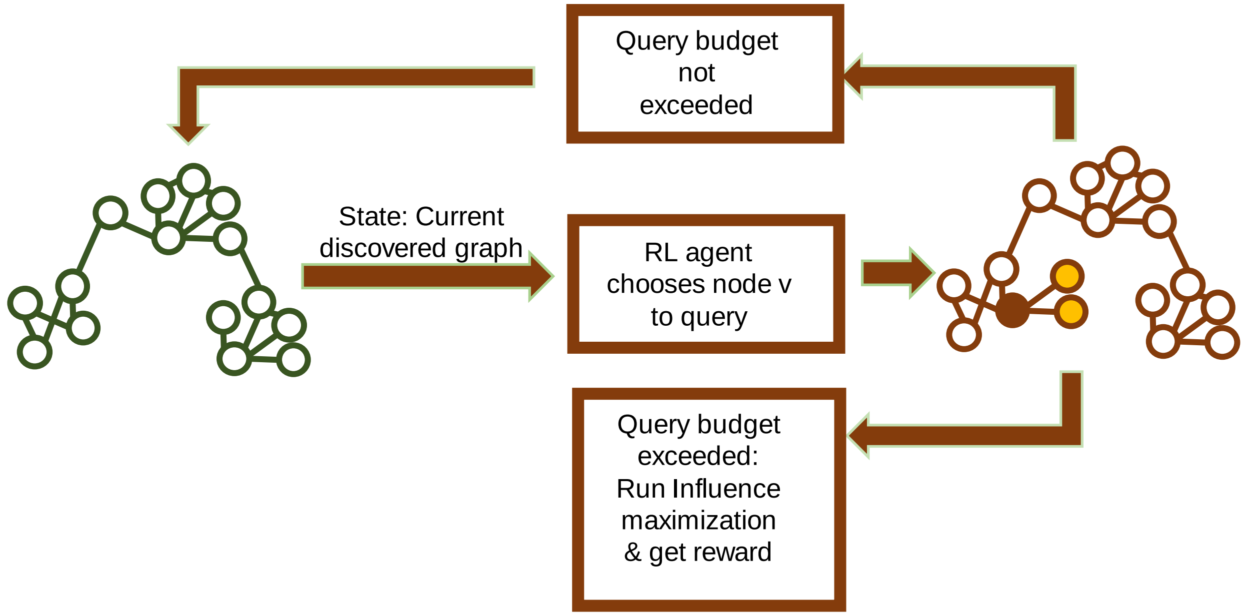
Next steps: Data to Deployment Pipeline Using an RL agent?

(with B. Ravindran & team, AAMAS 2020)



Next steps: Data to Deployment Pipeline Using an RL agent?

(with B. Ravindran & team, AAMAS 2020)



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

How Did the Projects Get Launched

:

Collaboration of

AI researchers, Social work researchers, Homeless Shelters

Started via discussion with social work professor:
Focused on problem, rather than starting with a solution approach

Support as academics: Will provide AI expertise

Outline

Public Health

- *Information dissemination & behavior change: Social networks*
- *Health program adherence: Passive via ML vs Active via bandits*
- *COVID-19: Agent-based modeling*

Conservation

Health Program Adherence
Maternal & Child Care in India

(Under submission)

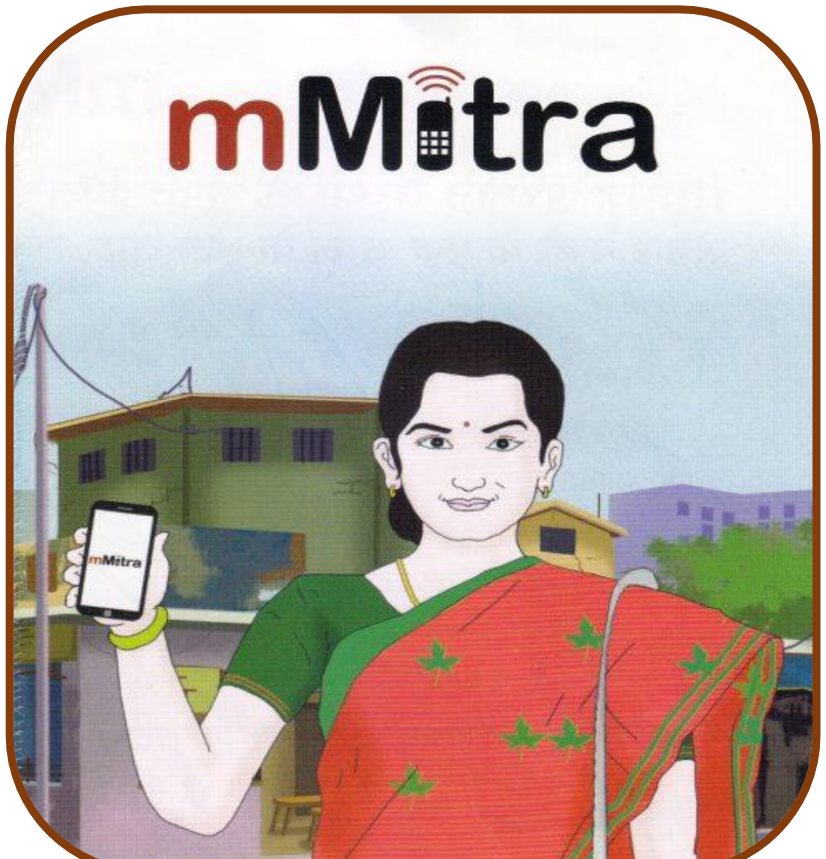
India: Woman dies in childbirth every 15 min; 4 of 10 children too thin/short

- *ARMMAN: 18 Million women enrolled, 160000 health workers…*
- *mMitra: Weekly call to new/expectant moms; friendly 3 minute messages about health*
- *mMitra: Significant benefits shown; 2.2 million women enrolled*
- *Unfortunately, significant fraction low-listeners or drop-outs*

armman

(Advancing Reduction in Mortality and Morbidity of Mothers, Children and Neonates)

Delivering India's Future



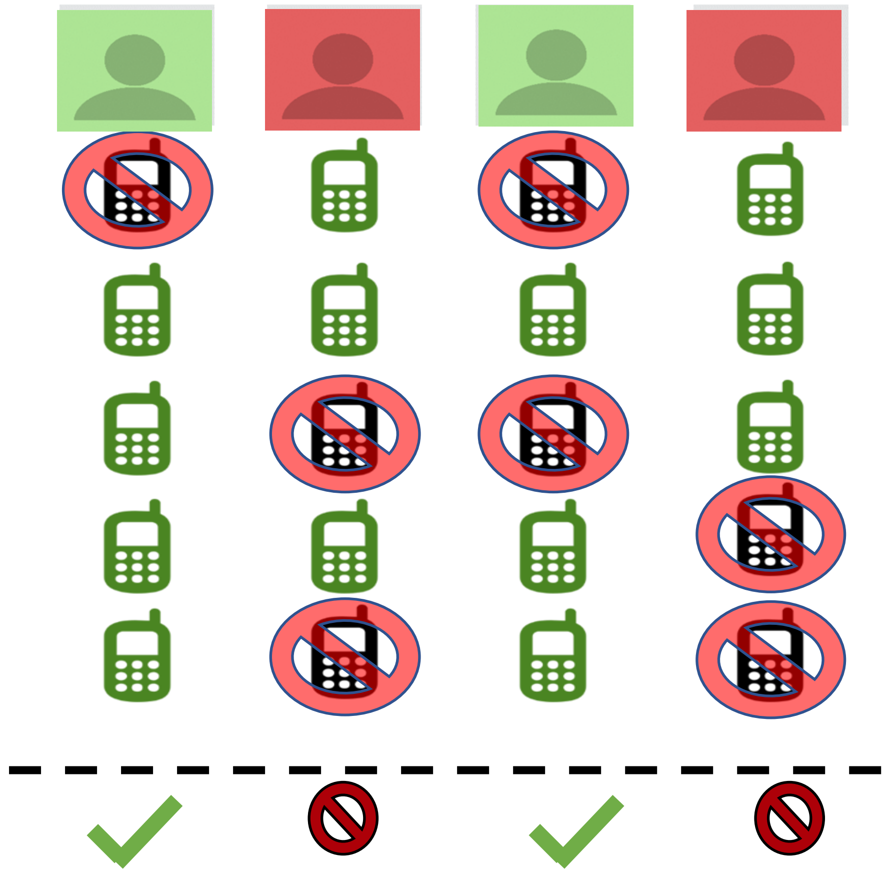
Passive Adherence Monitoring Maternal & Child Care in India

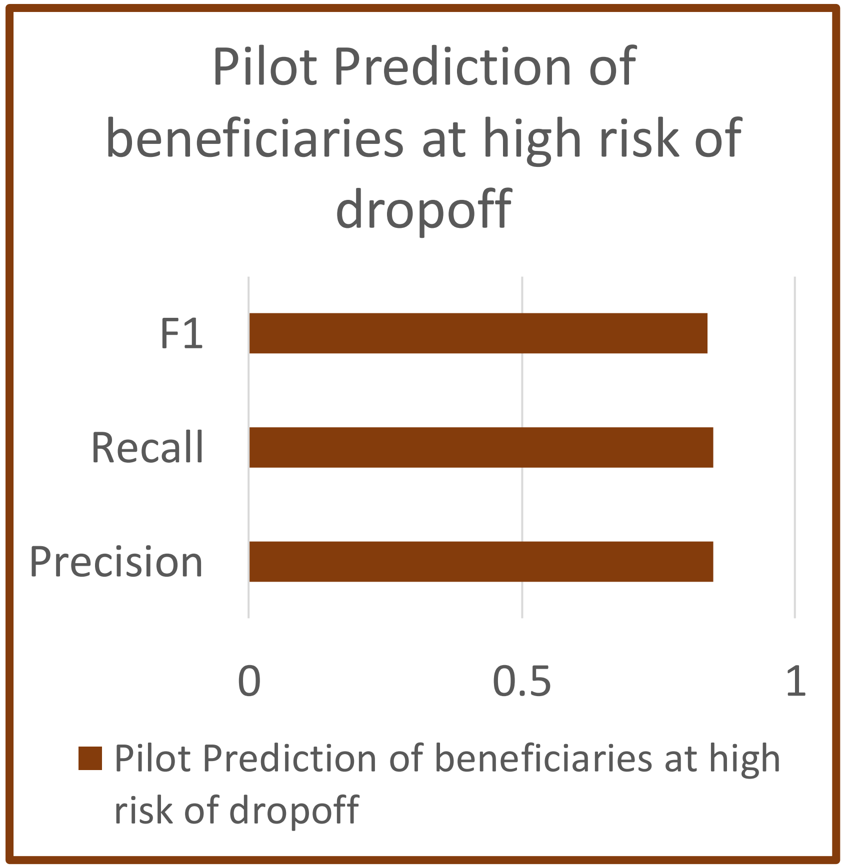
(with B Ravindran IIT Madras)

Predict beneficiaries likely to drop out: Allows ARMMAN to focus intervention

- *Neural networks for prediction: Extensive tests with past data*
- *Results of pilot with 18000 beneficiaries: High precision, recall, accuracy*

- ***Prediction software deployed: helps 300,000 beneficiaries in mMitra***





ARMMAN Pilot

- *18000 Beneficiaries*

  Nov & Dec 2019
- *Test: Jan-April 2020*

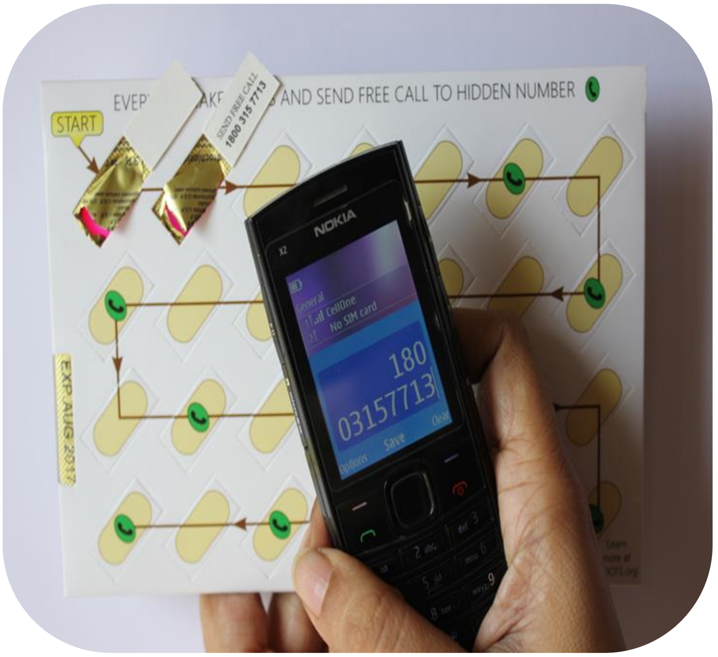
Passive Adherence Monitoring Preventing Tuberculosis in India
(KDD 2019)

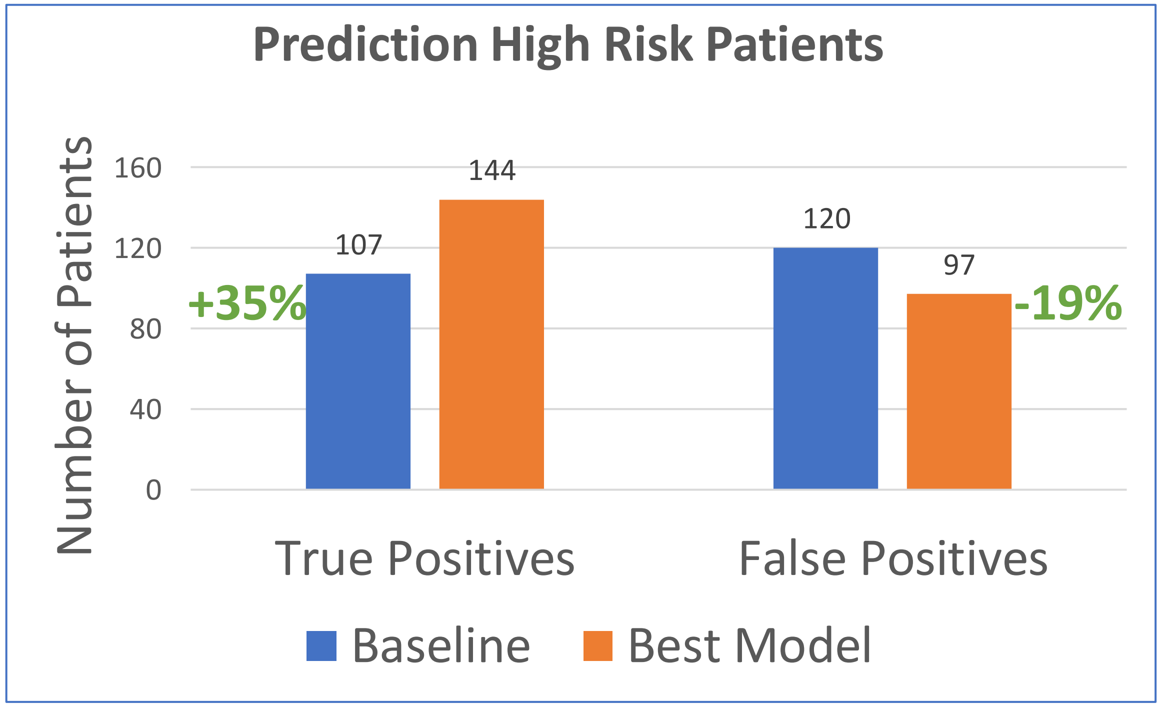
Killian

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

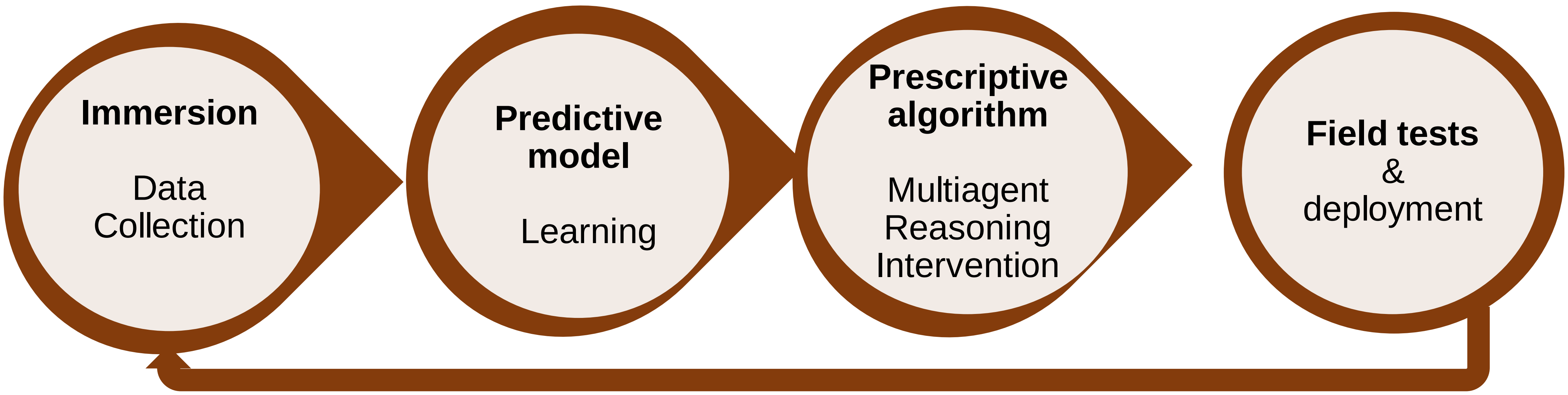
- *Non-adherence to TB Treatment: Digital adherence tracking via daily phone calls*
- *Intervene before patients miss dose*
- *Predict adherence risk from phone call patterns?*
- *Results from Mumbai, India: 15,000 patients, 1.5 million phone calls*

everwell





Intervention Reasoning: Active Adherence Monitoring



Health worker calls, patients do not call

Intervention Scheduling with Scarce Data: Passive vs Active Adherence Monitoring

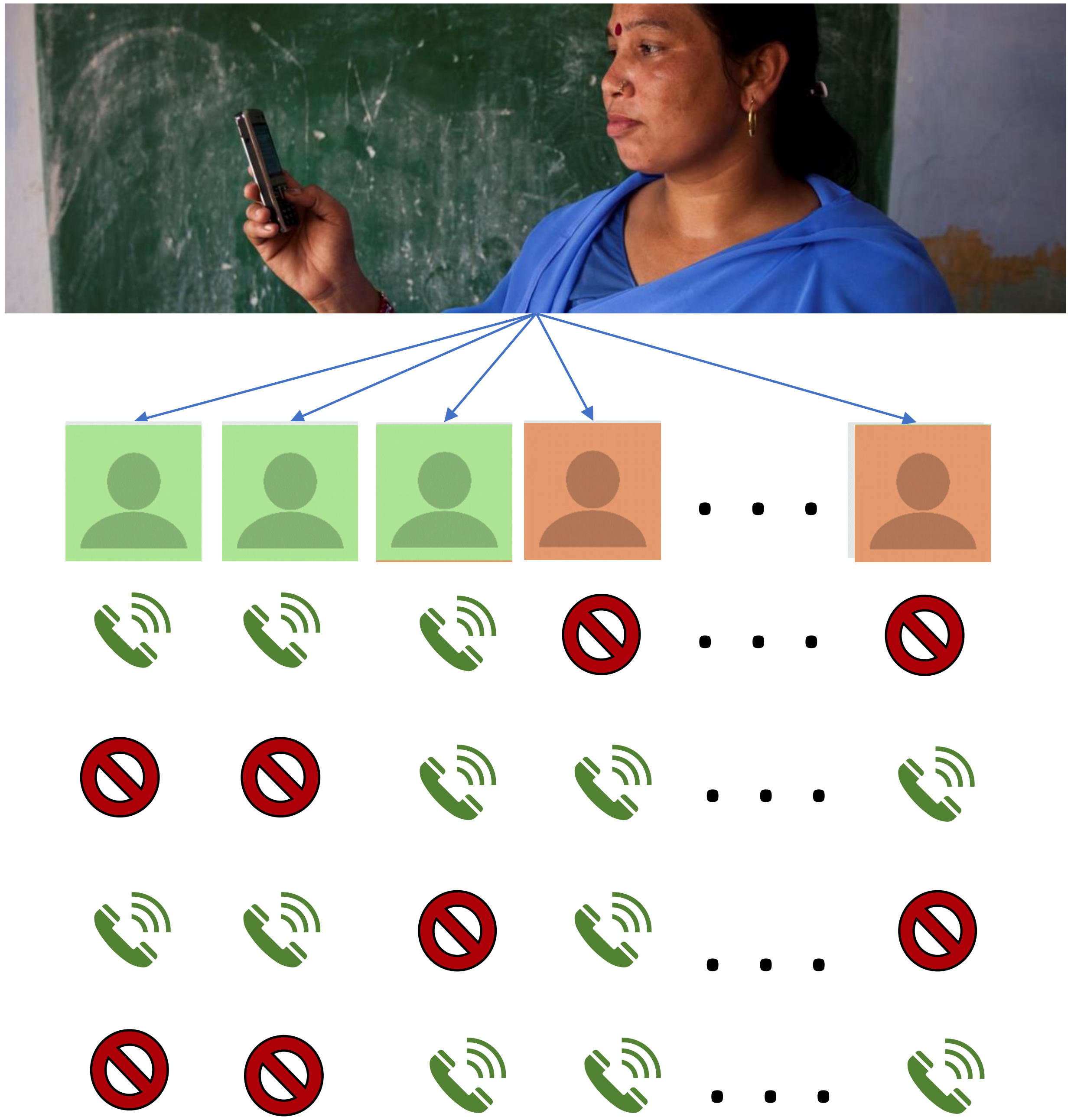
(Under submission)


Mate


Killian

Health worker

Call patients: Track, improve adherence



Challenge:

- *Large number of patients (N)*
- *Which ‘k’ patients to call?*

Approach:

- *Adherence Restless Bandits*

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

Intervention Scheduling with Scarce Data: Adherence Restless Bandits(A-RMAB)

(Under submission)


Mate Killian

Restless multiarmed bandits (RMAB)

Adherence RMAB (A-RMAB):

- *Each arm has binary latent state {0, 1}*
- *0= not-adhering; 1= adhering*

	not-adhering	adhering
not-adhering	0.90	0.10
adhering	0.05	0.95

Intervention Scheduling with Scarce Data: Adherence Restless Bandits(A-RMAB)

(Under submission)

Mate

Killian

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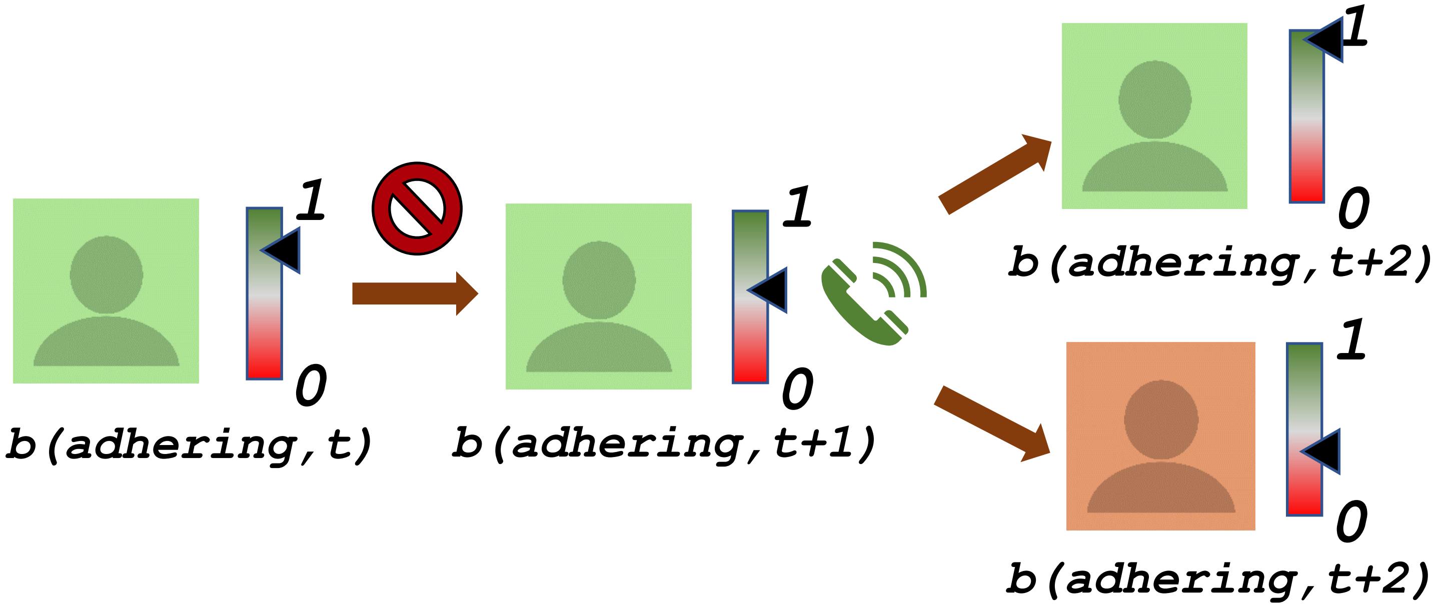
	not-adhering	adhering
not-adhering	0.90	0.10
adhering	0.05	0.95

When arm not played

- *No observation*
- *Instead, compute belief of adherence*

When arm is played

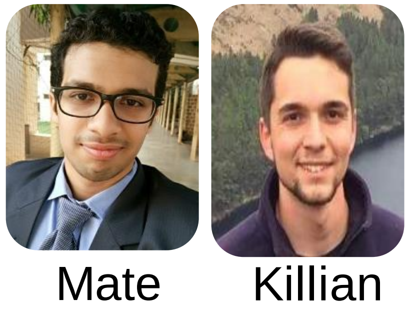
- *Observe current state*
- *Higher chance of adhering next round*



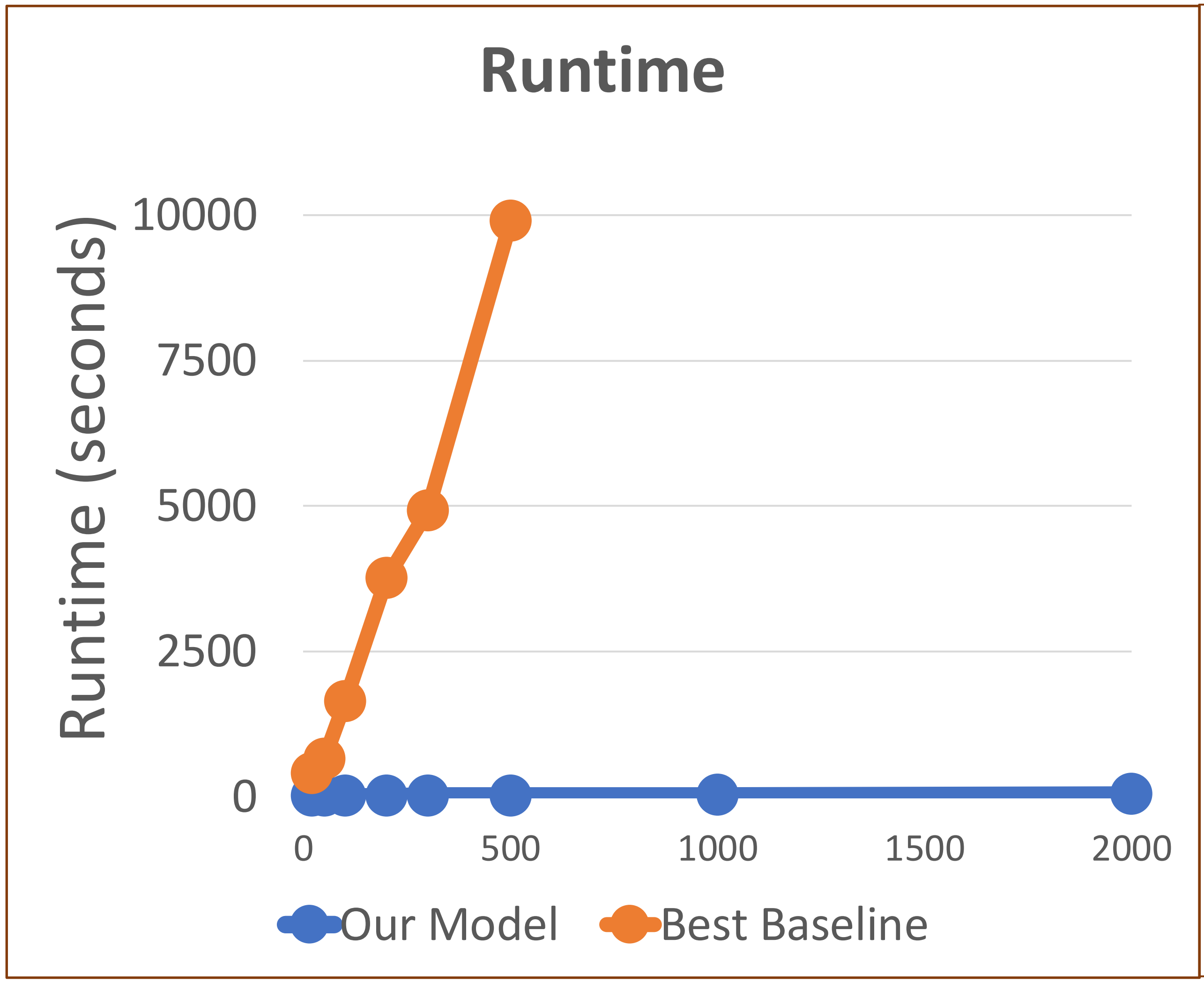
*P(**adhering** | call) > P(**adhering** | no call)*

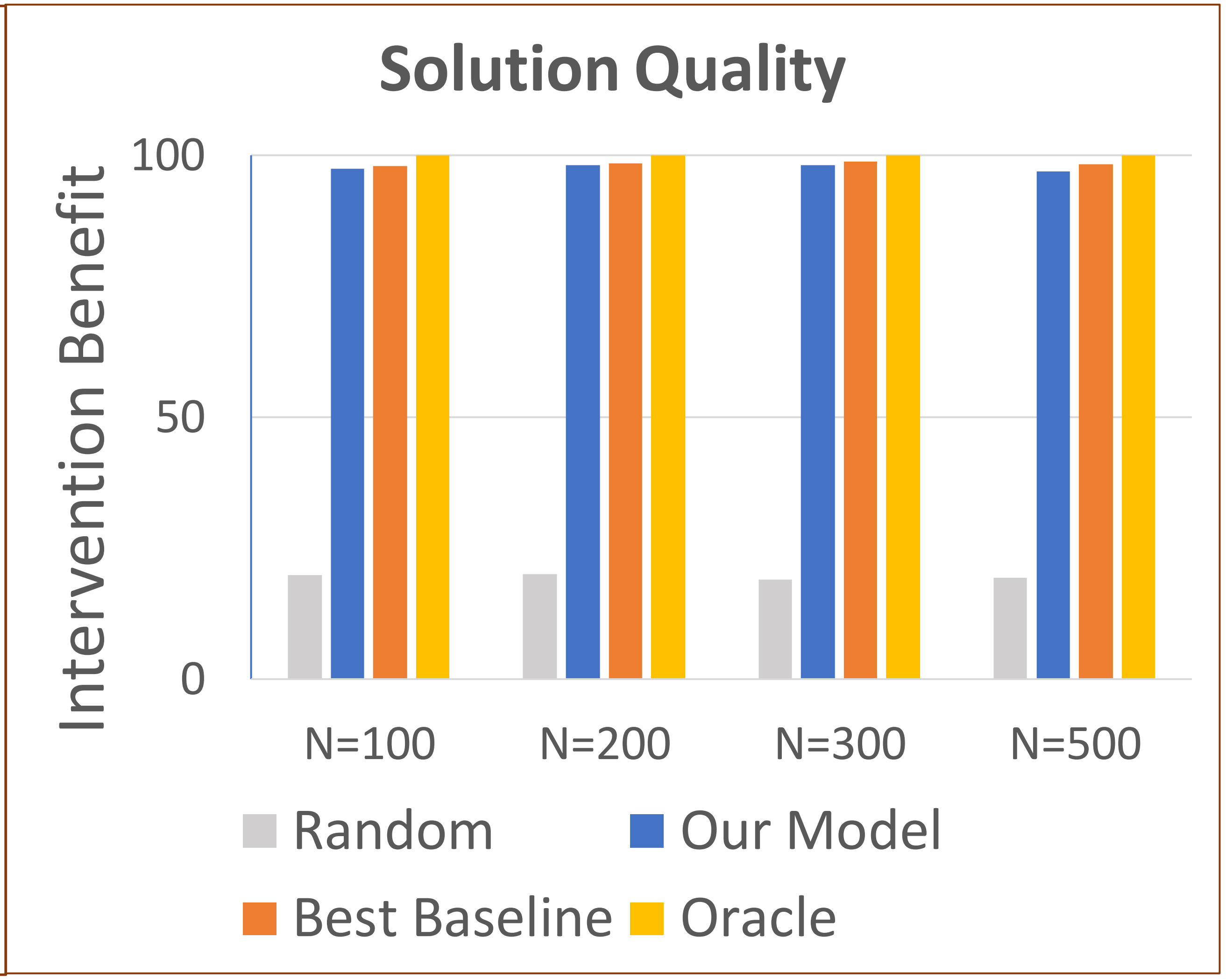
Photo Credit: IntraHealth International (CC BY-NC-SA 3.0 via https://www.intrahealth.org/)

Intervention Scheduling with Scarce Data: Adherence Restless Bandits(A-RMAB)



➢ ***Orders of magnitude speedup with no solution quality loss***





How Did the Projects Get Launched

:

Launched 6 separate
AI for Social Good Projects

Google, Academics, NGO

Workshop at Google Research India for Matchmaking

Support from Google: Funding, Compute, Google Collaboration

Outline

Public Health

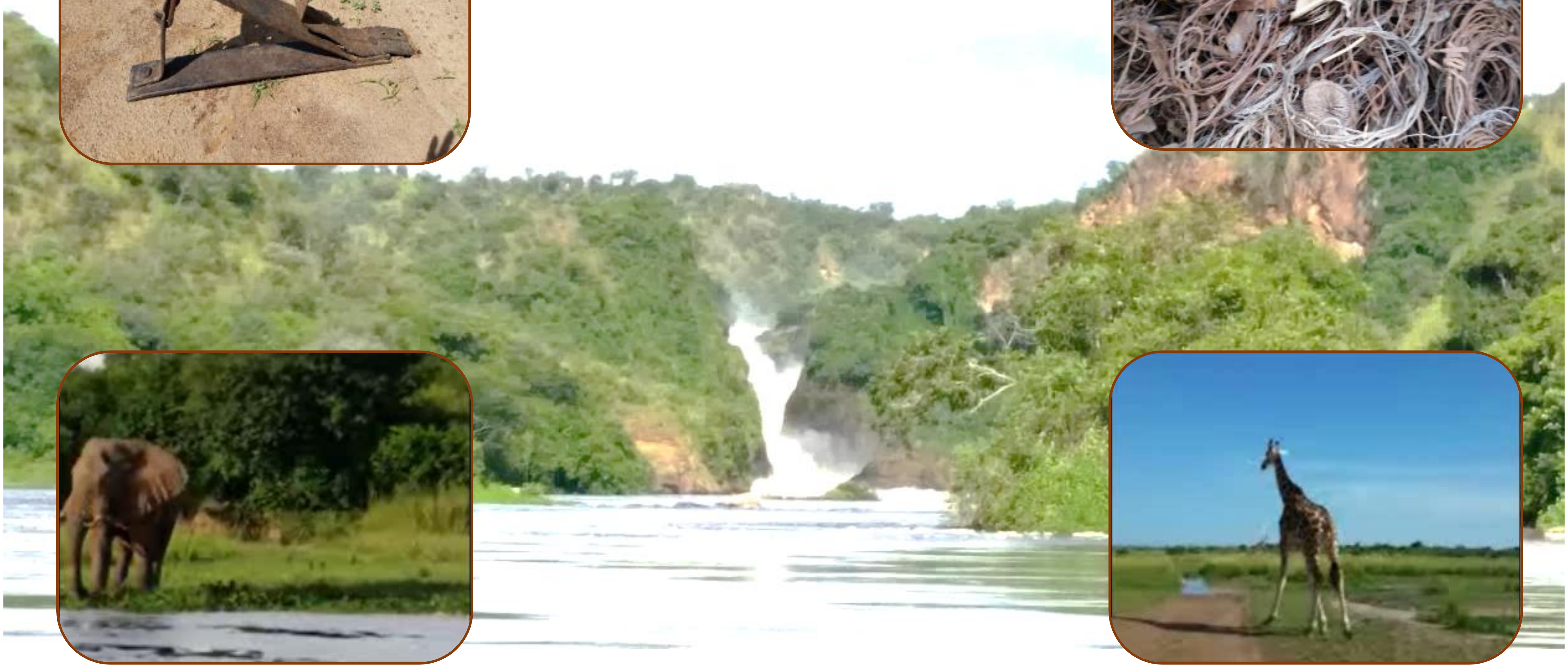
Conservation

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

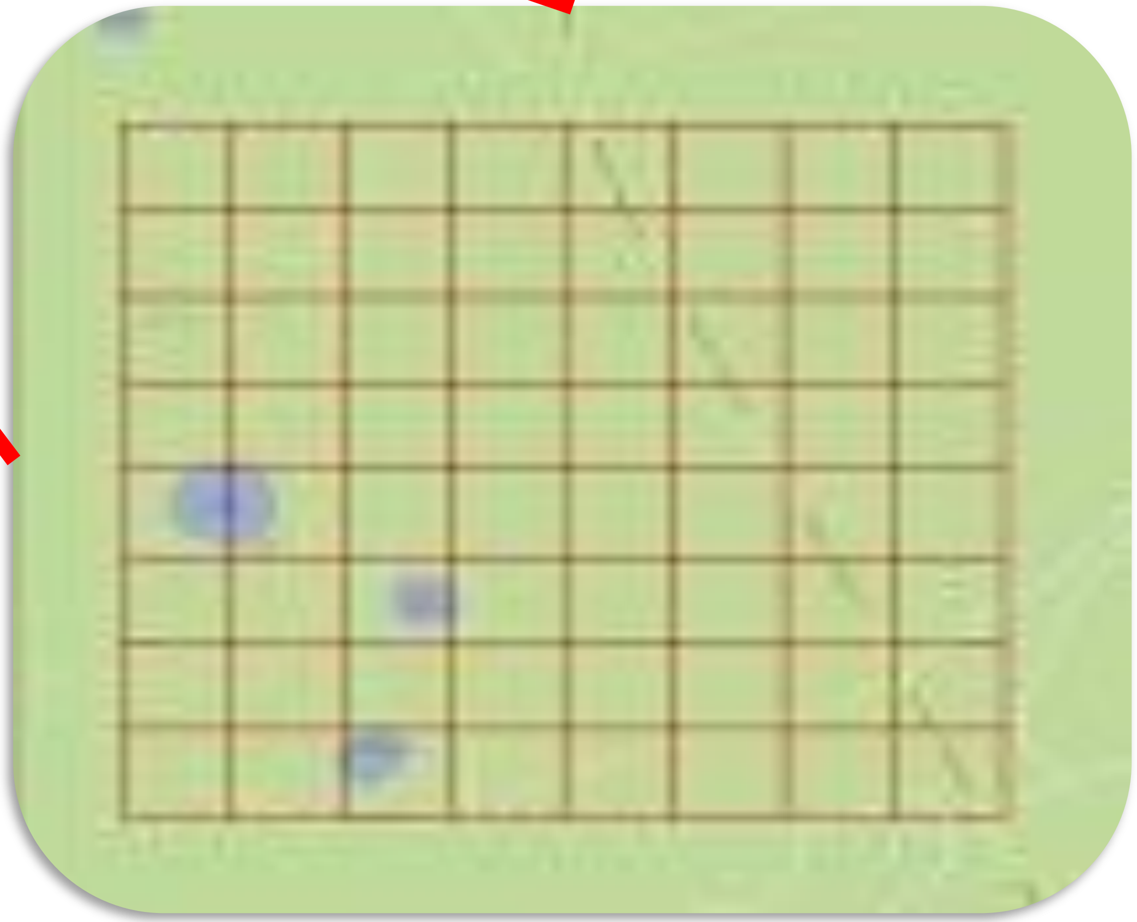
Poaching of Wildlife in Uganda
Limited Intervention (Ranger) Resources to Protect Forests

Snare or Trap

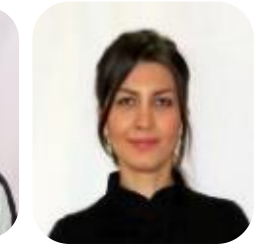
Wire snares

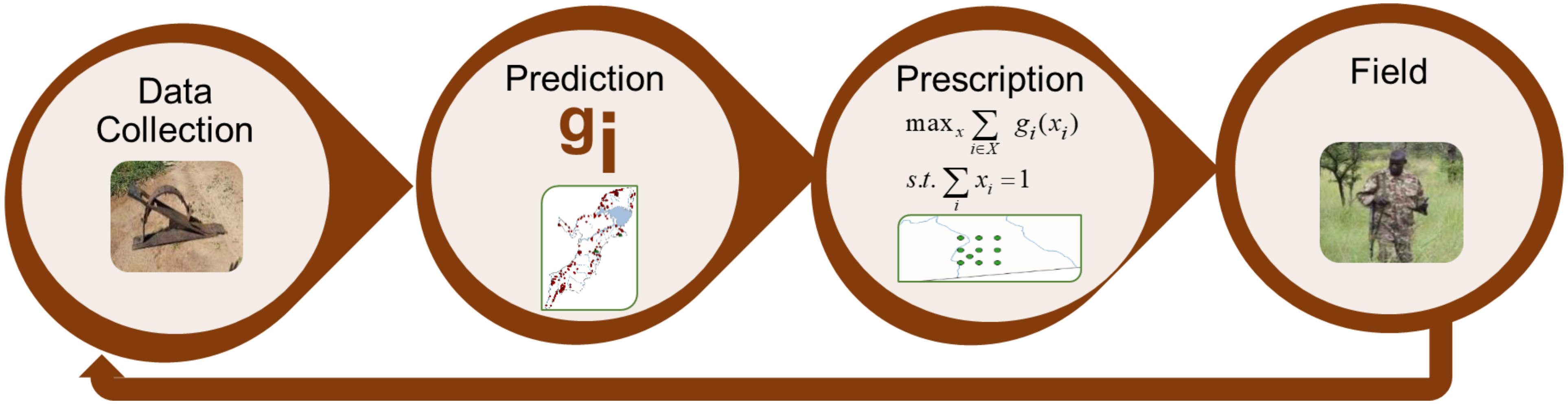


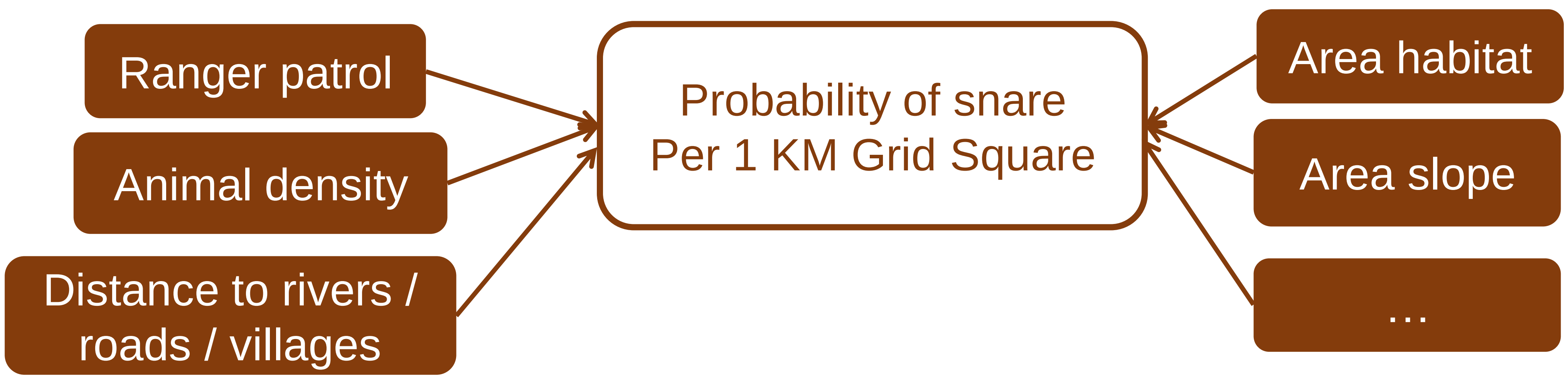
Focus on Threat prediction
Diving up the area into 1 Km x 1 Km Grid cells



Learning Poacher Model: Uncertainty in Observations







Record: No Attack (NEG)

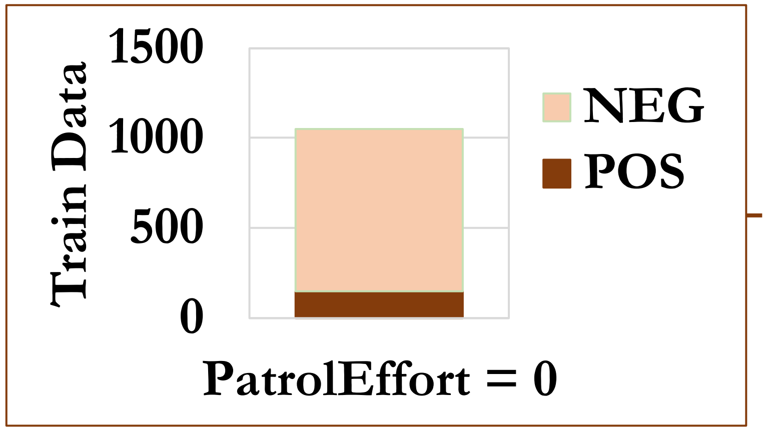
Record: Attack (POS)

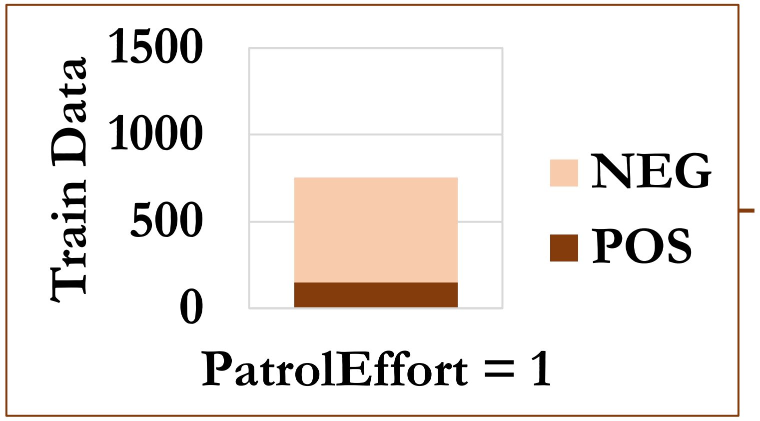

Gholami

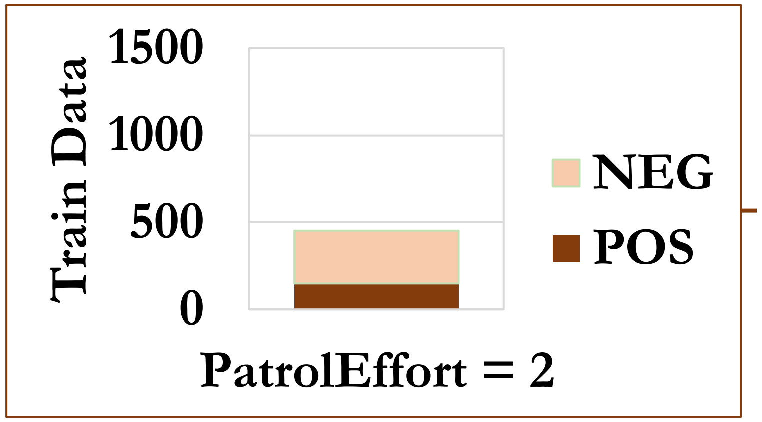
Poacher Modeling
Imperfect Observation Ensemble Model

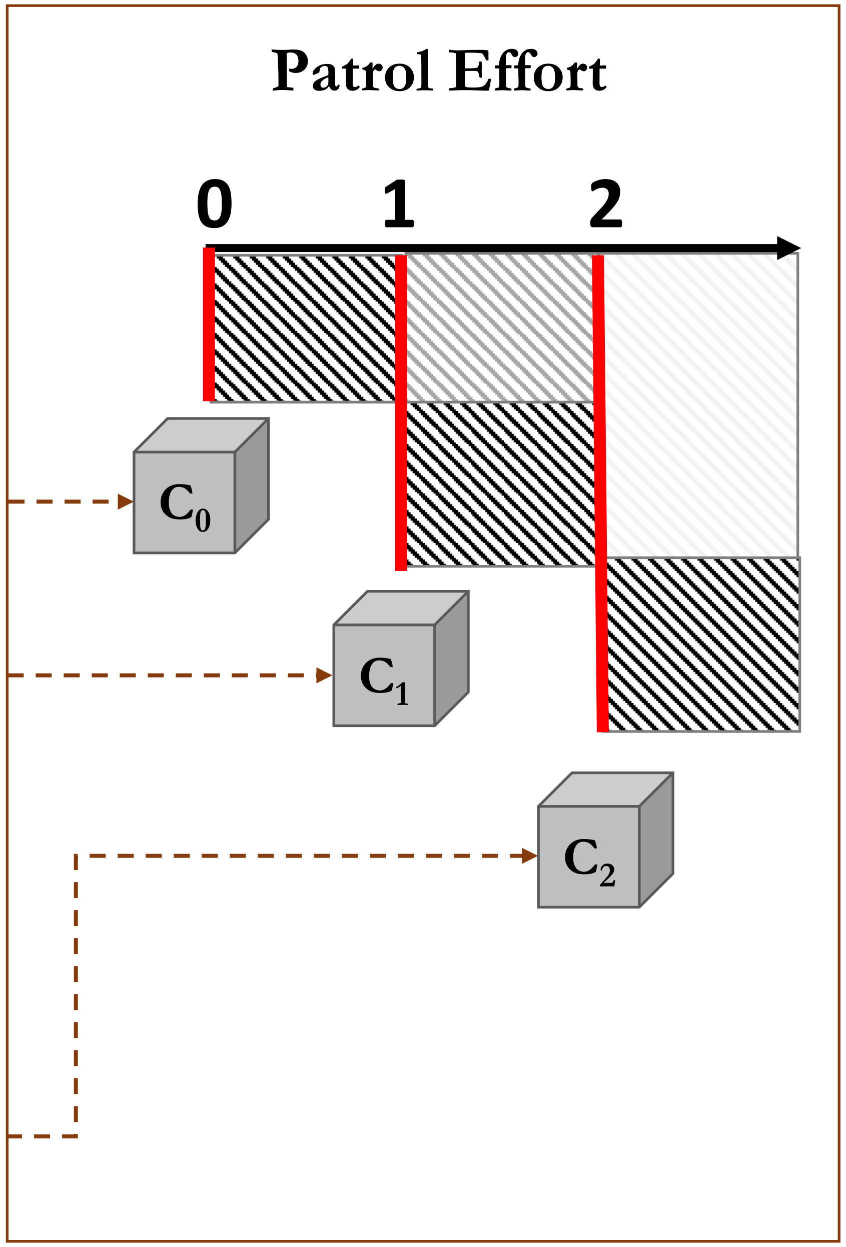
Training: Filtered Datasets

Predict: Ensemble of Classifiers





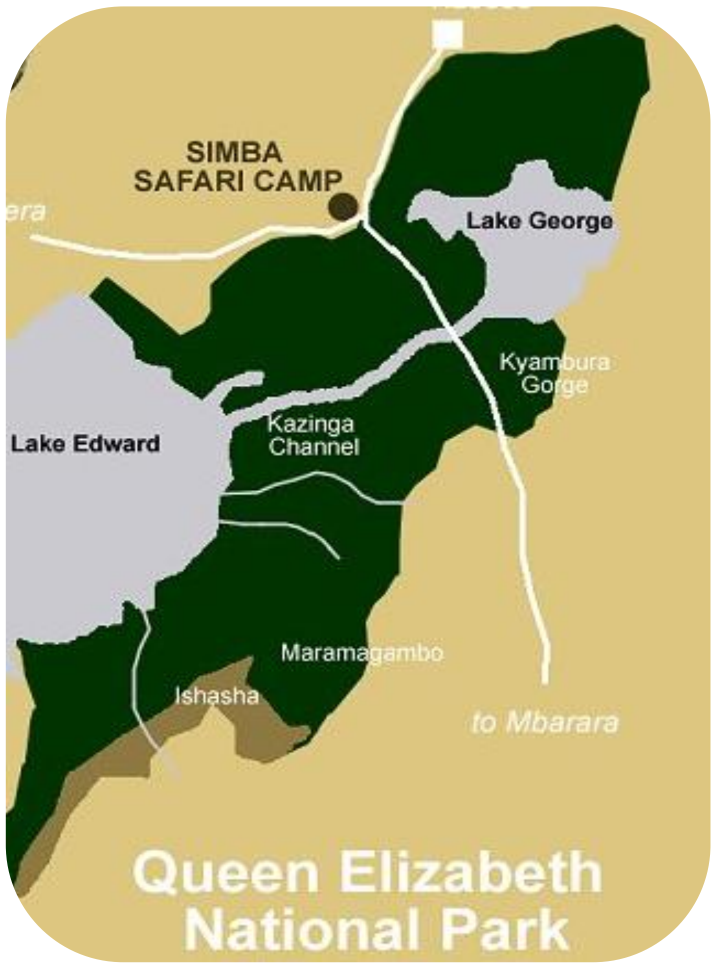


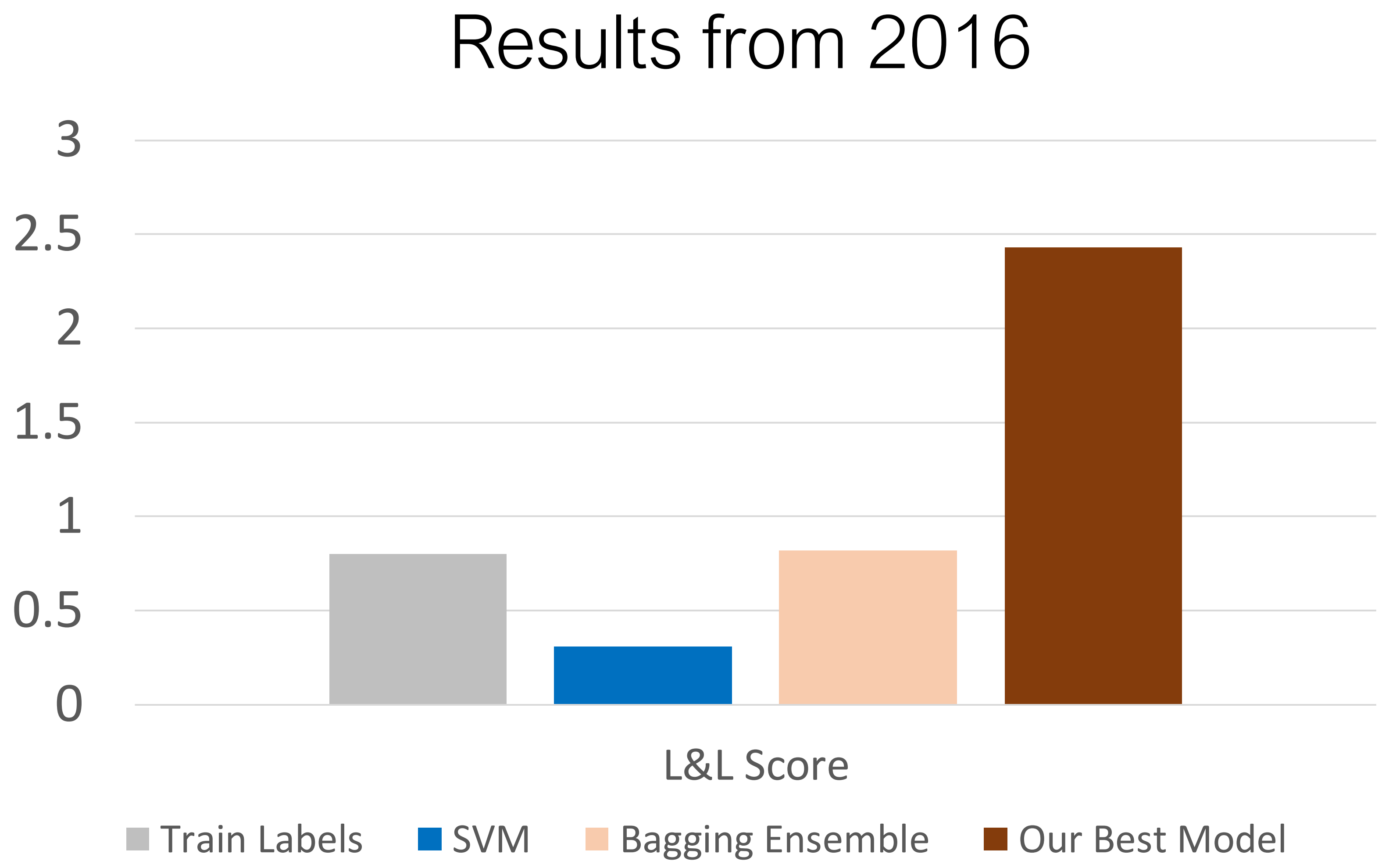


PAWS: Protection Assistant for Wildlife Security Adversary Model in the Lab

Gholami

Poacher Behavior Prediction





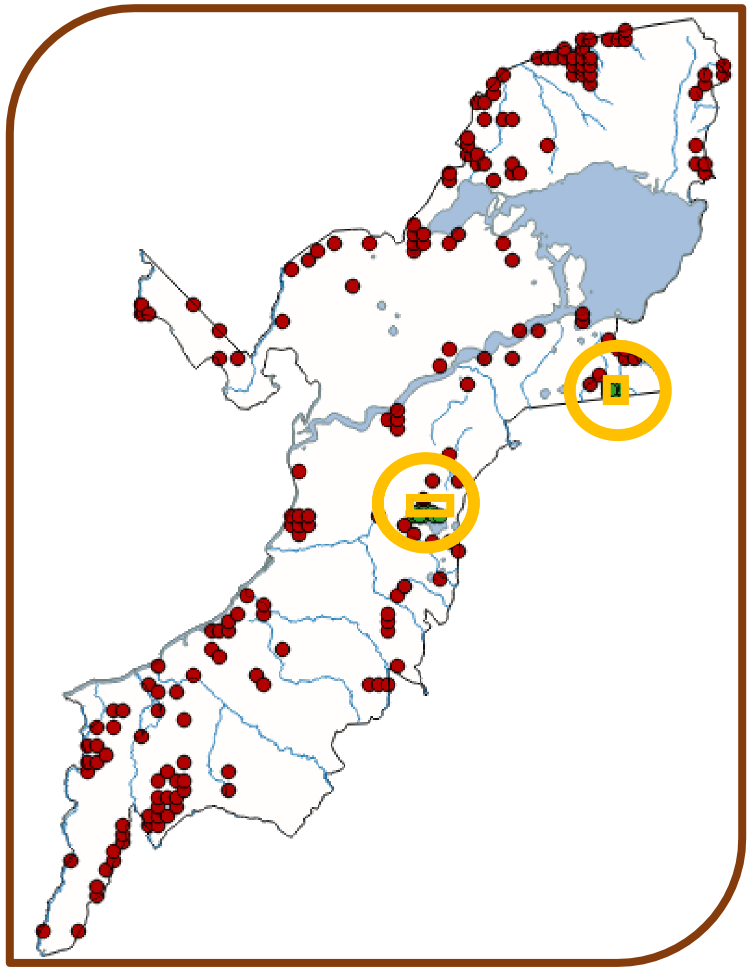
PAWS: First Pilot in the Field

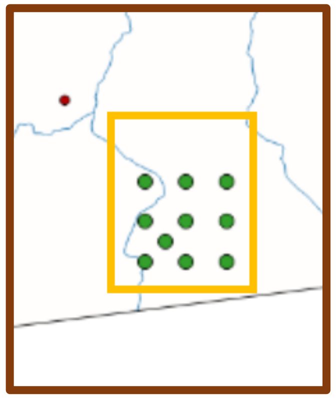
(AAMAS 2017)

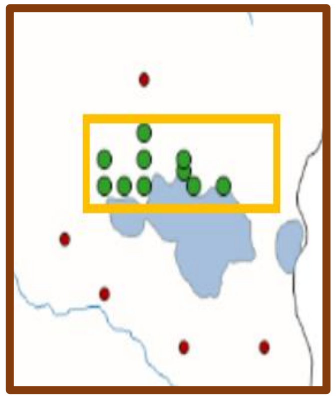
Ford

Gholami

- Two 9-sq.km areas, infrequent patrols







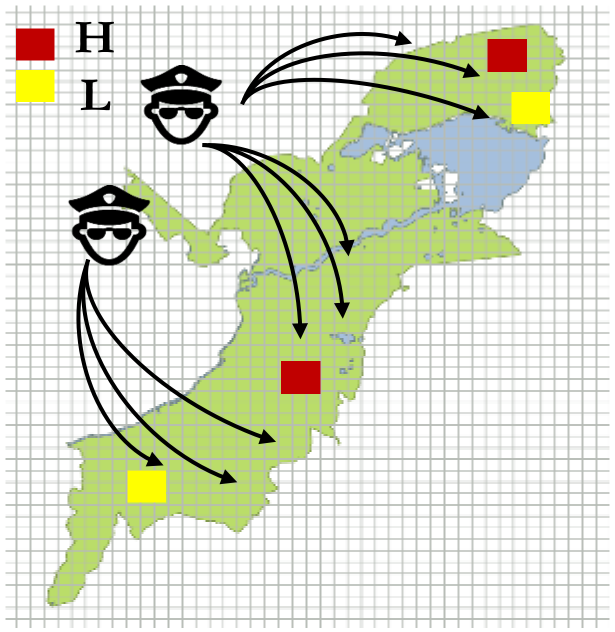
- Poached elephant
- 1 elephant snare roll
- 10 Antelope snares

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

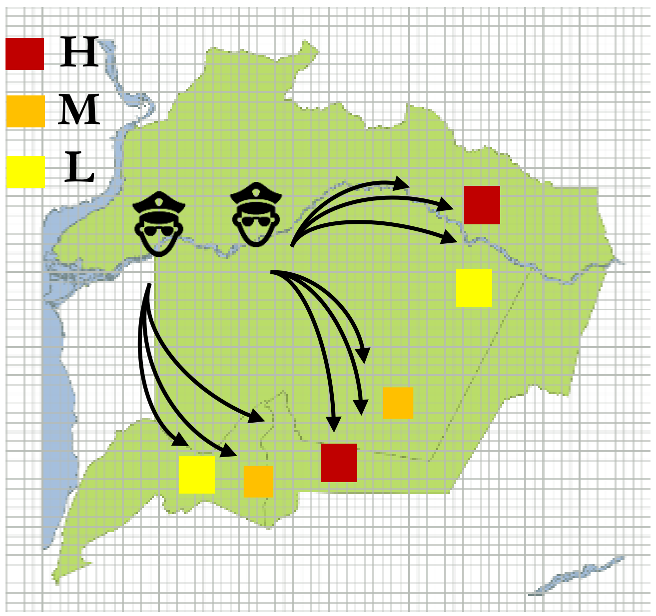
(ECML PKDD 2017, ICDE 2020)

Ford

Gholami

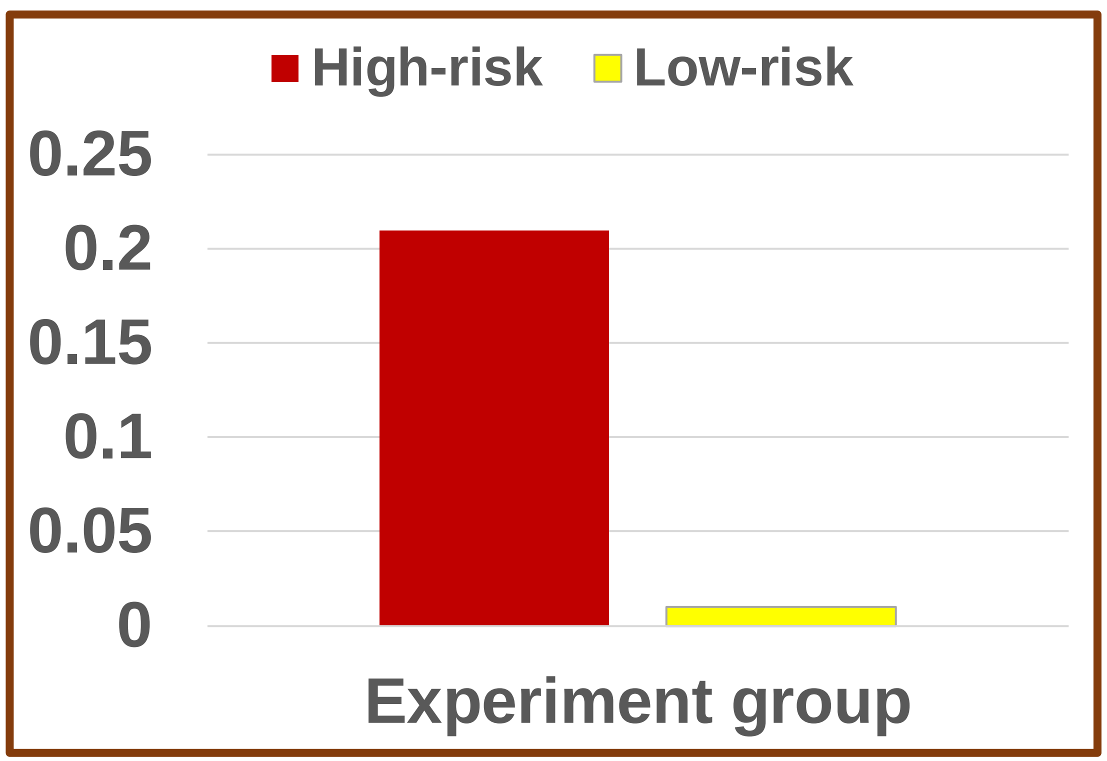


Queen Elizabeth National Park

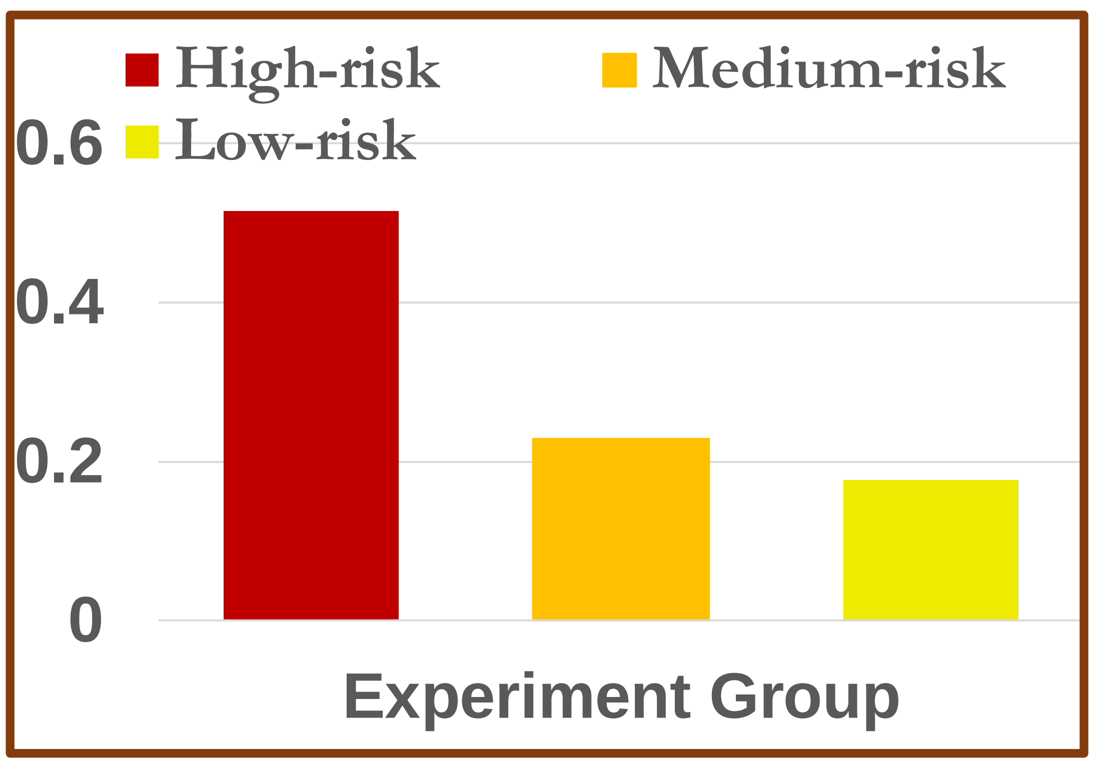


Murchison Falls National Park

Snares per patrolled sq. KM



Snares per patrolled sq. KM



PAWS Real-world Deployment
Cambodia: Srepok Wildlife Sanctuary

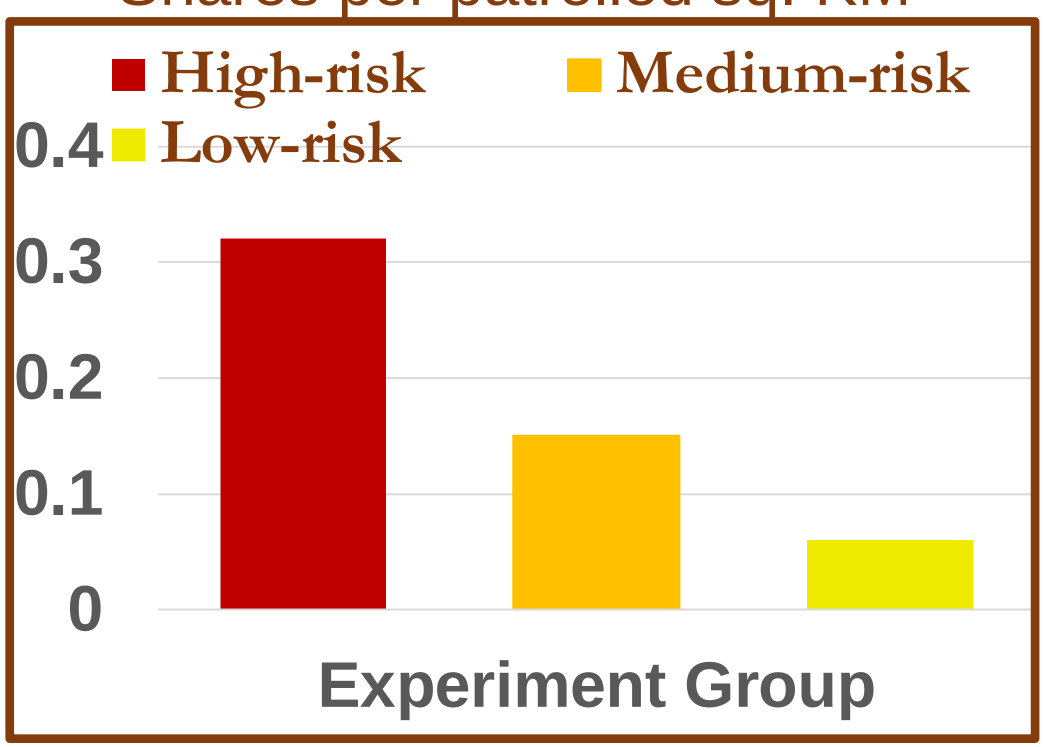
(ICDE 2020)

Xu

"@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



- *521 snares/month our tests*

  vs

- *101 snares/month 2018*

PAWS GOES GLOBAL with SMART platform!!

SMART

WWF

PEACE PARKS FOUNDATION · THE GLOBAL SOLUTION

WCS

AI for Earth

Protect Wildlife
800
National Parks
Around the Globe

Also: Protect Forests, Fisheries…

How Did the Projects Get Launched

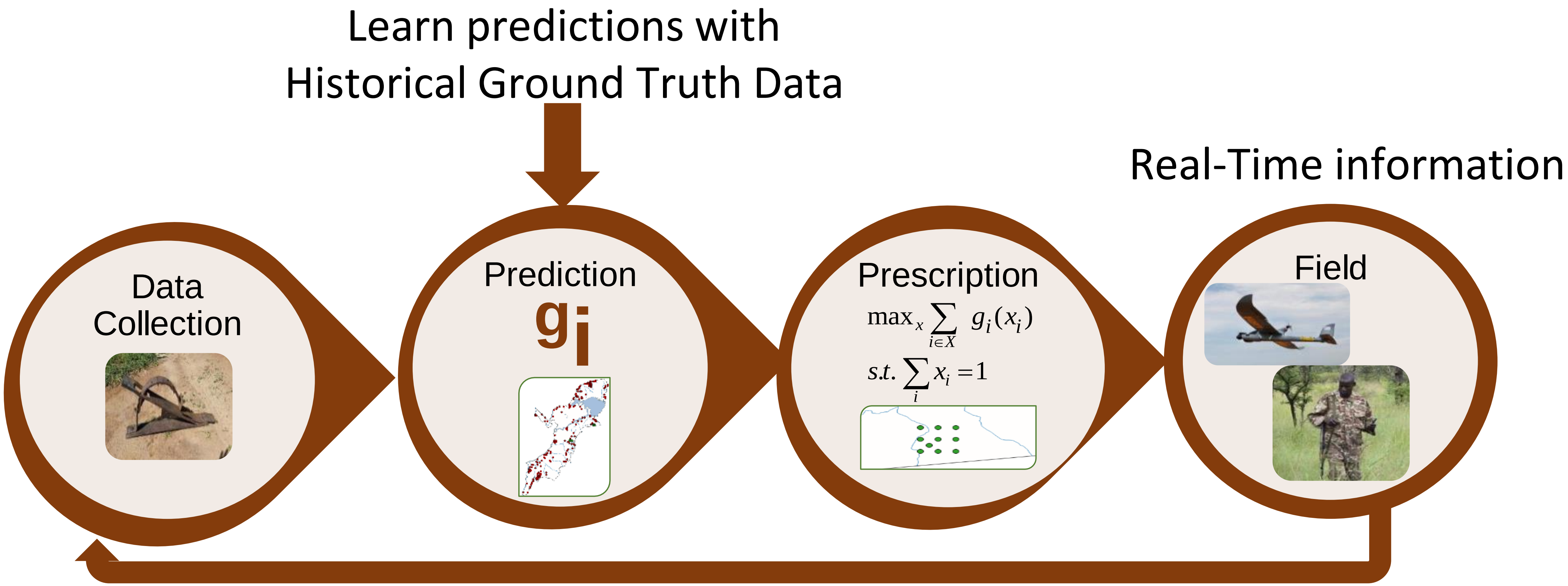
:

Launched PAWS project for Wildlife conservation

Met WCS officials in person in Uganda to get the project going

Support as academics: Will provide AI expertise

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

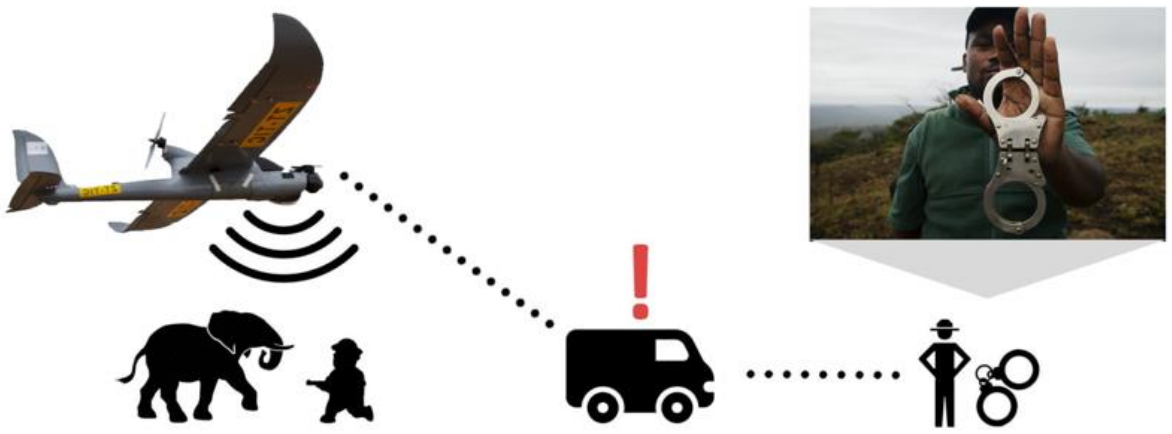


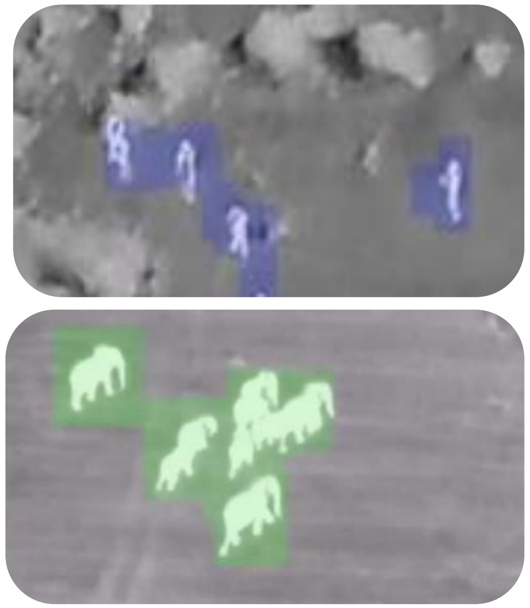
Green Security Games: Integrating Real-Time "SPOT" Information

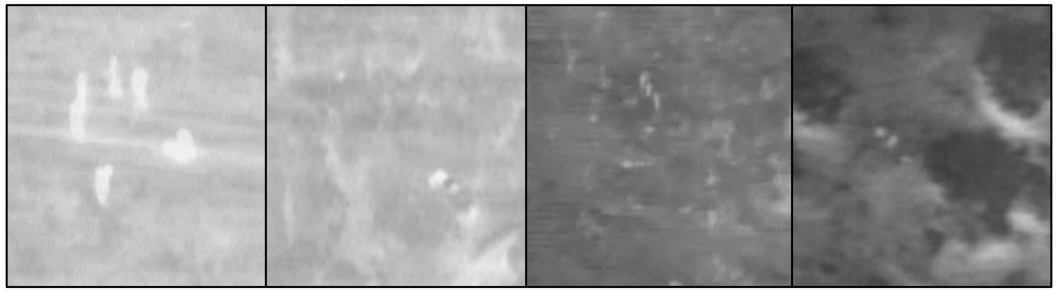
(IAAI 2018)

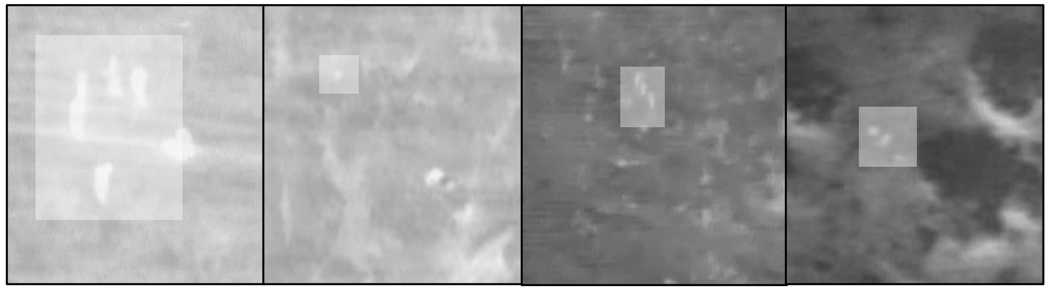

Bondi

Air Shepherd
The Lindbergh Foundation









Goal: automatically find poachers

How Did the Projects Get Launched

:

Launched SPOT project for Wildlife conservation

Air Shepherd sent an email to us to collaborate

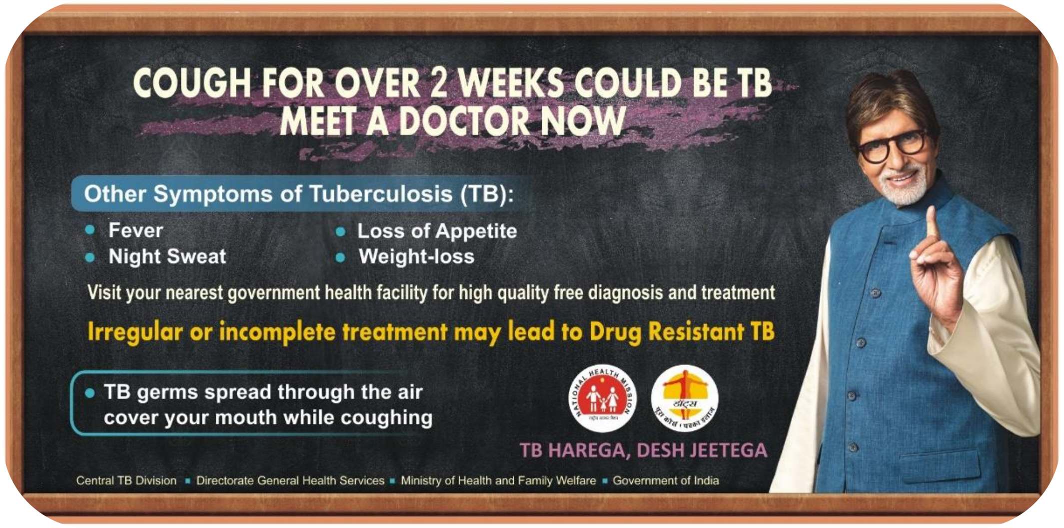
Support as academics: Will provide AI expertise

Three Key Takeaways

What are key problem types for AI for Social Good in public health & conservation?

What are some key AI research challenges (pay attention to models, not details)

How do we launch projects in AI for Social Good?



Future: AI Research for Social Impact

- It is possible to simultaneously advance AI research & achieve social impact

- 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

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)

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

@MilindTambe_AI