

Societal Computing Practicum

Interdisciplinary Research

Fei Fang

feifang@cmu.edu

Outline

- ▶ Definition
- ▶ Significance
- ▶ Trend
- ▶ Key Challenges
- ▶ Towards Successful Interdisciplinary Research
- ▶ My Experience and Lessons Learned
- ▶ Q&A

Definition

- ▶ No universally accepted definition
- ▶ What is your definition?
- ▶ Key elements and characteristics?

*Not just one discipline
cross departments*

Definition

- ▶ From National Institutes of Health (NIH)
 - ▶ Interdisciplinary research *integrates the analytical strengths of two or more often disparate scientific disciplines to solve a given problem.*

Definition

- ▶ From National Academies' report
 - ▶ Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.

Definition

- ▶ From [Aboelela et al, 2007]
 - ▶ Interdisciplinary research is any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process.

Definition

- ▶ What is considered interdisciplinary today might be considered disciplinary tomorrow
 - ▶ Philosophy called the mother of all sciences
 - ▶ As science develops, more subdivisions / disciplines arise
 - ▶ Artificial Intelligence is a typical example
 - ▶ At the intersection of: Cognitive Science, Statistics, Applied Math/Operations Research, Philosophy, Neuroscience, Linguistics

Definition

- ▶ Examples of established fields of study that are interdisciplinary

HCI

Robotics

Comp Bio

Computational Social Science / Political science / psychology
→ Biotech

Definition

- ▶ Examples of established fields of study that are interdisciplinary
 - ▶ Biochemistry
 - ▶ Biophysics
 - ▶ Social psychology
 - ▶ Geophysics
 - ▶ Informatics

Definition

► Examples of high-impact interdisciplinary work

► Manhattan Project - Atomic bomb

Moon landing

Computer

Robotics

Detecting bots in social network

ML, social science/marketing

How people are influenced, how people work together

CS, sociology, organizational theory, psychology

Definition

► Interdisciplinary research

- By a team with each team member having expertise in different disciplines (team work)
- By an individual who has expertise in multiple disciplines
 - How interdisciplinary are you? Test available:
<https://www.nature.com/news/how-interdisciplinary-are-you-1.18362>

Definition

- ▶ Interdisciplinary research by a team of experts in different disciplines is a special scenario of teamwork

Build a wall



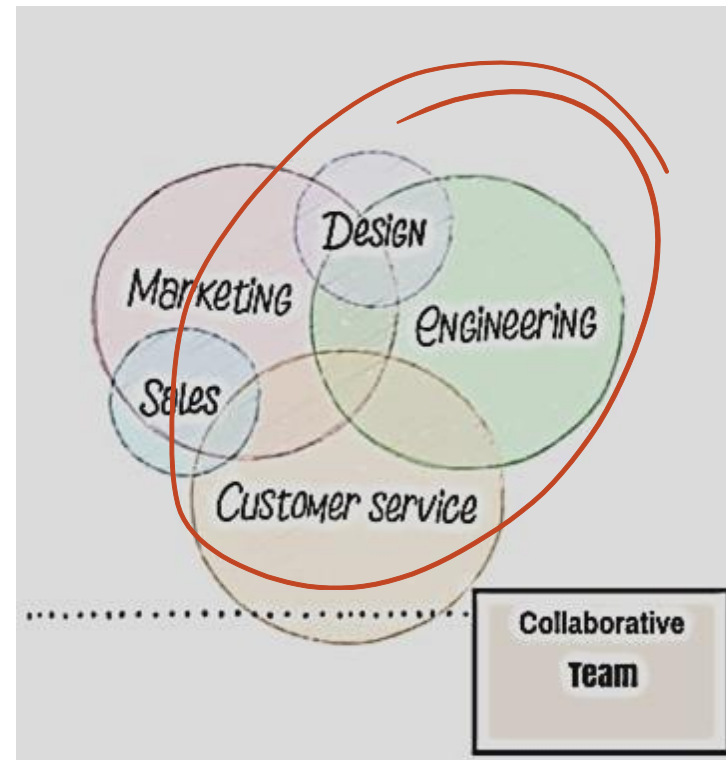
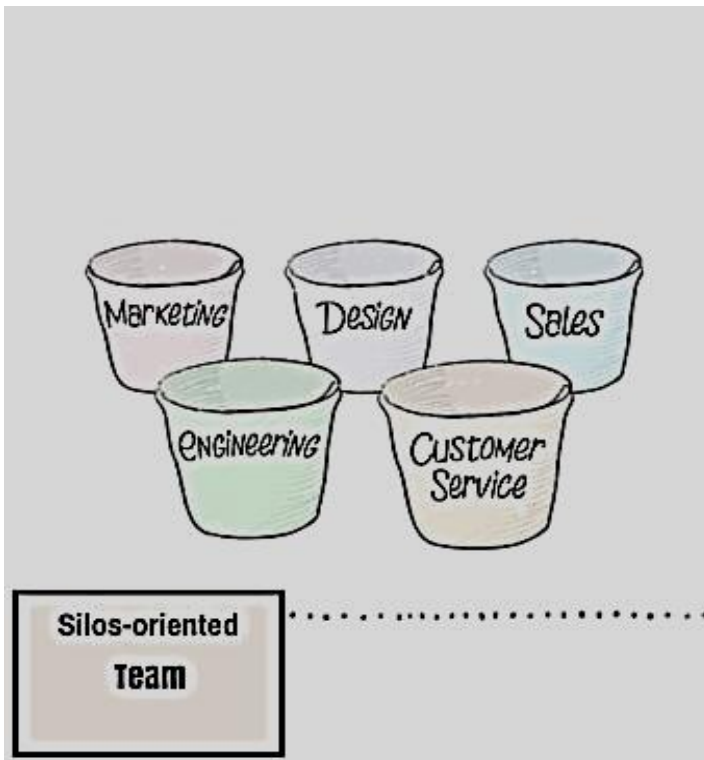
Group project



Definition

- ▶ Interdisciplinary research by a team of experts in different disciplines is a special scenario of teamwork

Teamwork in a corporation



Definition

- ▶ Interdisciplinary research by a team of experts in different disciplines is a special scenario of teamwork

Multidisciplinary – Interdisciplinary – Transdisciplinary

	Problem Definition	Research Style	Presentation of Findings
<u>Multidisciplinary</u>	Same question but different paradigm OR different but related questions	“Parallel play”	Separate publications by participants from each discipline
Interdisciplinary	Described/defined in language of at least two fields, using multiple models or intersecting models	Drawn from more than one, with multiple data sources and varying analysis of same data	Shared publications, with language intelligible to all involved fields
Transdisciplinary	Stated in new language or theory that is broader than any one discipline	Fully synthesized methods, may result in new field	Shared publications, using at least some new language developed for translation across traditional lines

Outline

- ▶ Definition
- ▶ Significance
- ▶ Trend
- ▶ Key Challenges
- ▶ Towards Successful Interdisciplinary Research
- ▶ My Experience and Lessons Learned
- ▶ Q&A

Significance

► Why interdisciplinary research is significant?

- Many real world problem are too complex to be solved by methods/ approaches in one discipline.

Climate change, Governmental problem, Health care

- Creative solutions for existing problems
↳ inspired by minds with different expertise
- Ask innovative questions

Significance

- ▶ Drive people to ask questions and solve problems that have never come up before
 - ▶ Push fields forward and accelerate scientific discovery
 - ▶ Important research ideas often transcend the scope of a single discipline or program
- ▶ Complex and pressing questions and problems cannot be adequately addressed by people from just one discipline
 - ▶ E.g., climate change, health services, sustainability
 - ▶ Widely considered a hothouse for innovation
 - ▶ Facilitate application of knowledge in a specific area
 - ▶ Conventional approaches may not succeed
- ▶ Fully answer critical questions

Significance

► From NIH

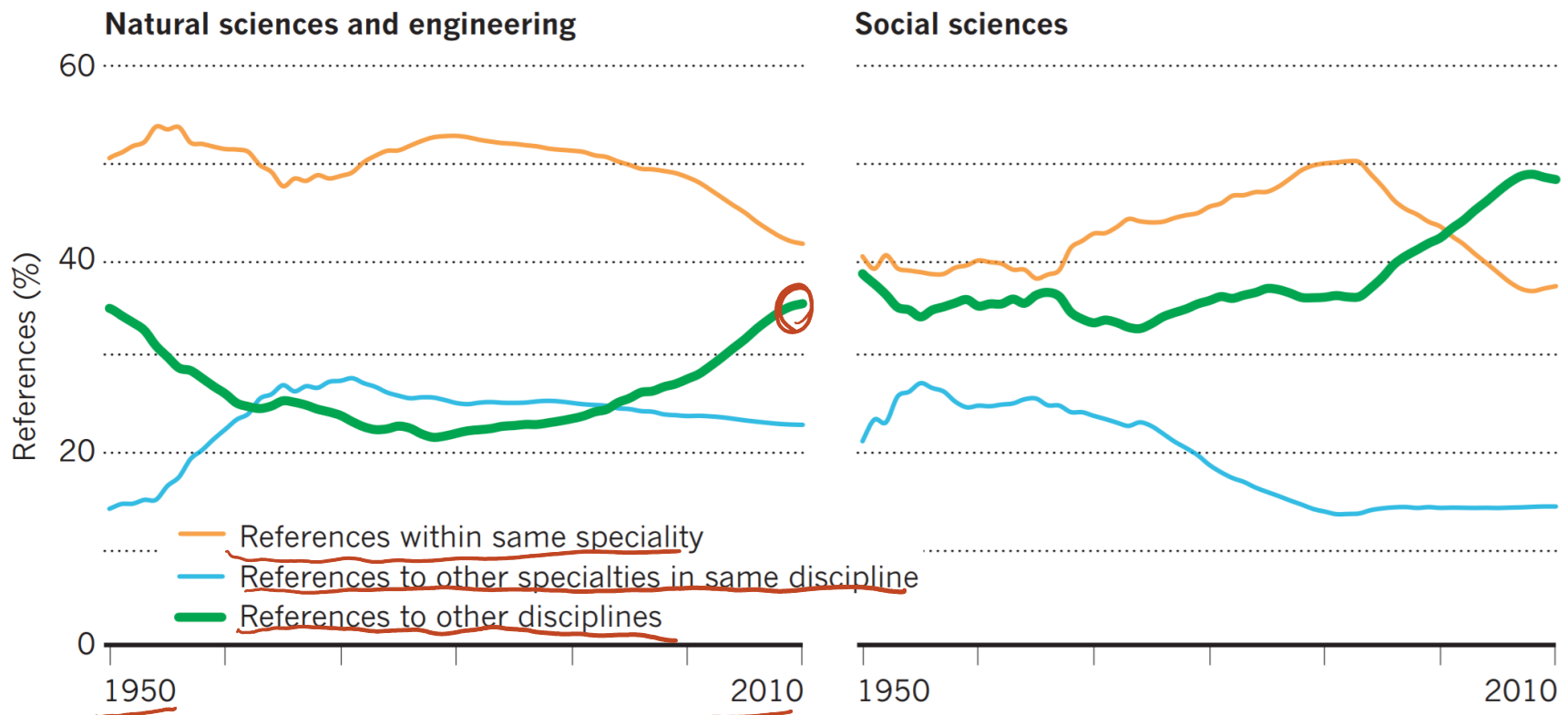
- By engaging seemingly unrelated disciplines, *traditional gaps in terminology, approach, and methodology might be gradually eliminated*. With roadblocks to potential collaboration removed, a true meeting of minds can take place: one that broadens the scope of investigation into problems, yields fresh and possibly unexpected insights, and may even give birth to new hybrid disciplines that are more analytically sophisticated.

Outline

- ▶ Definition
- ▶ Significance
- ▶ Trend
- ▶ Key Challenges
- ▶ Towards Successful Interdisciplinary Research
- ▶ My Experience and Lessons Learned
- ▶ Q&A

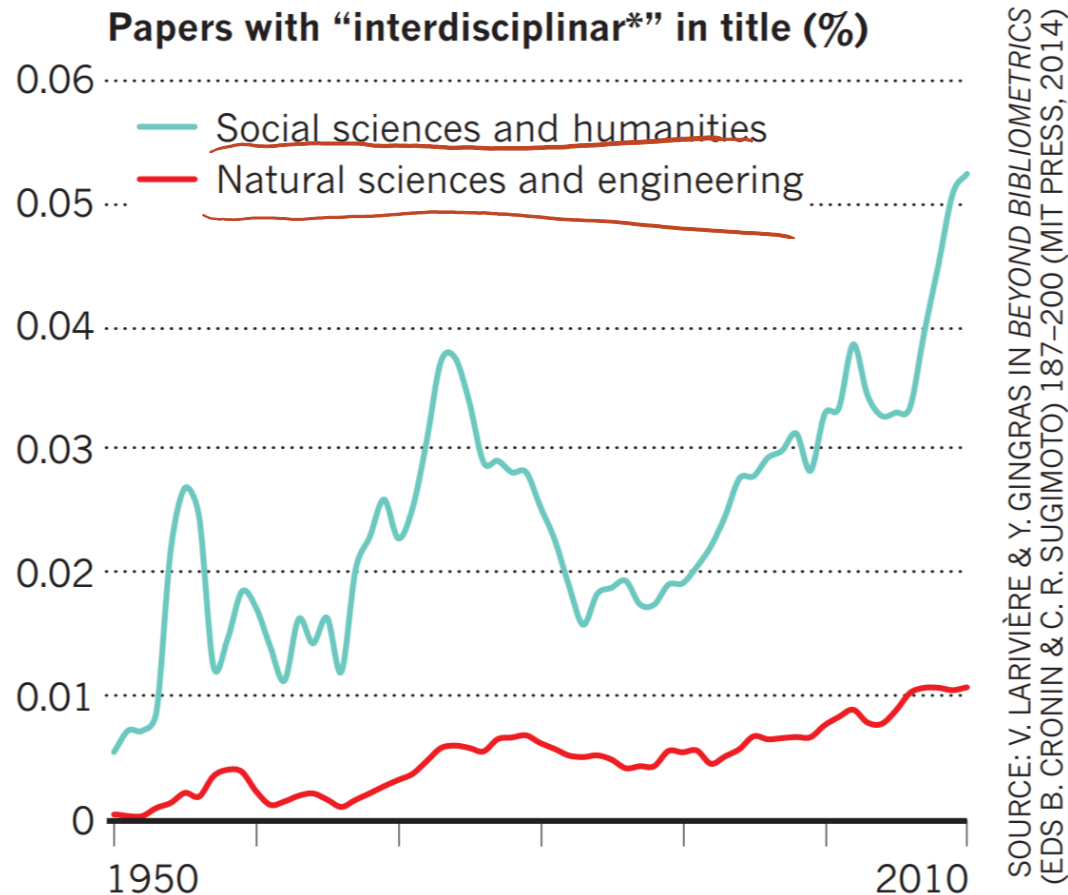
Trend

- ▶ Interdisciplinary research is on the rise
 - ▶ ~1/3 of the references in scientific papers now point to other disciplines



Trend

► Interdisciplinary research is on the rise

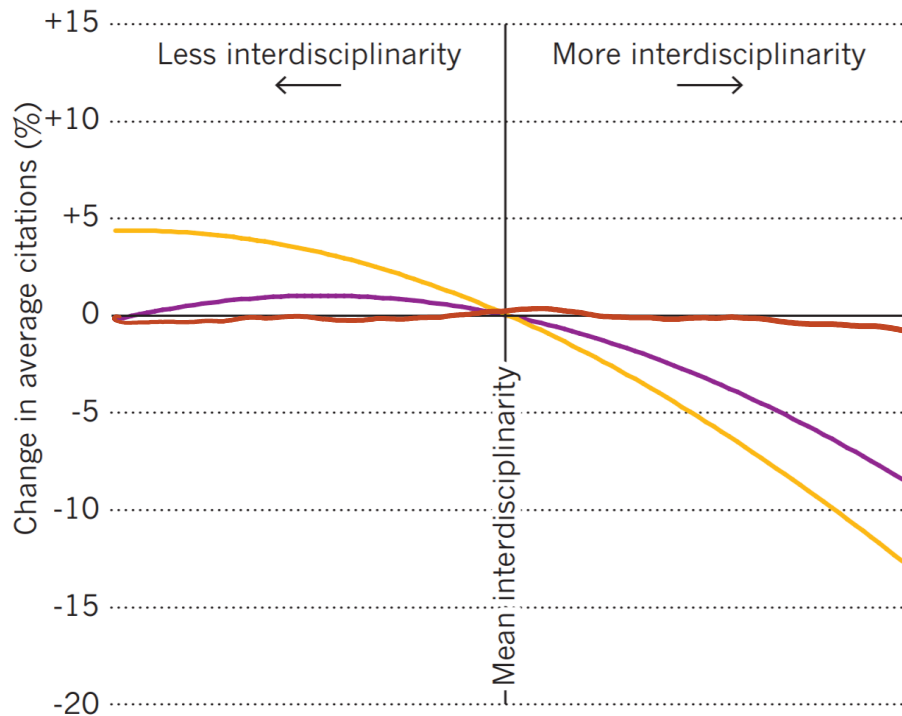


Trend

► Interdisciplinary research takes time to have an impact

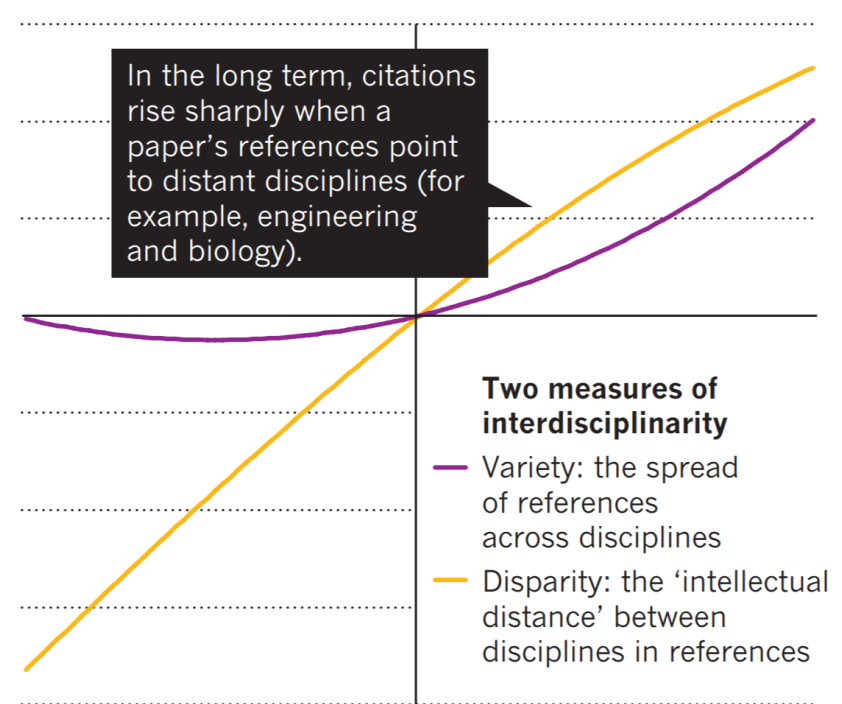
Three years after publication: less impact

Citations decrease as a paper's interdisciplinarity increases.



Thirteen years after publication: more impact

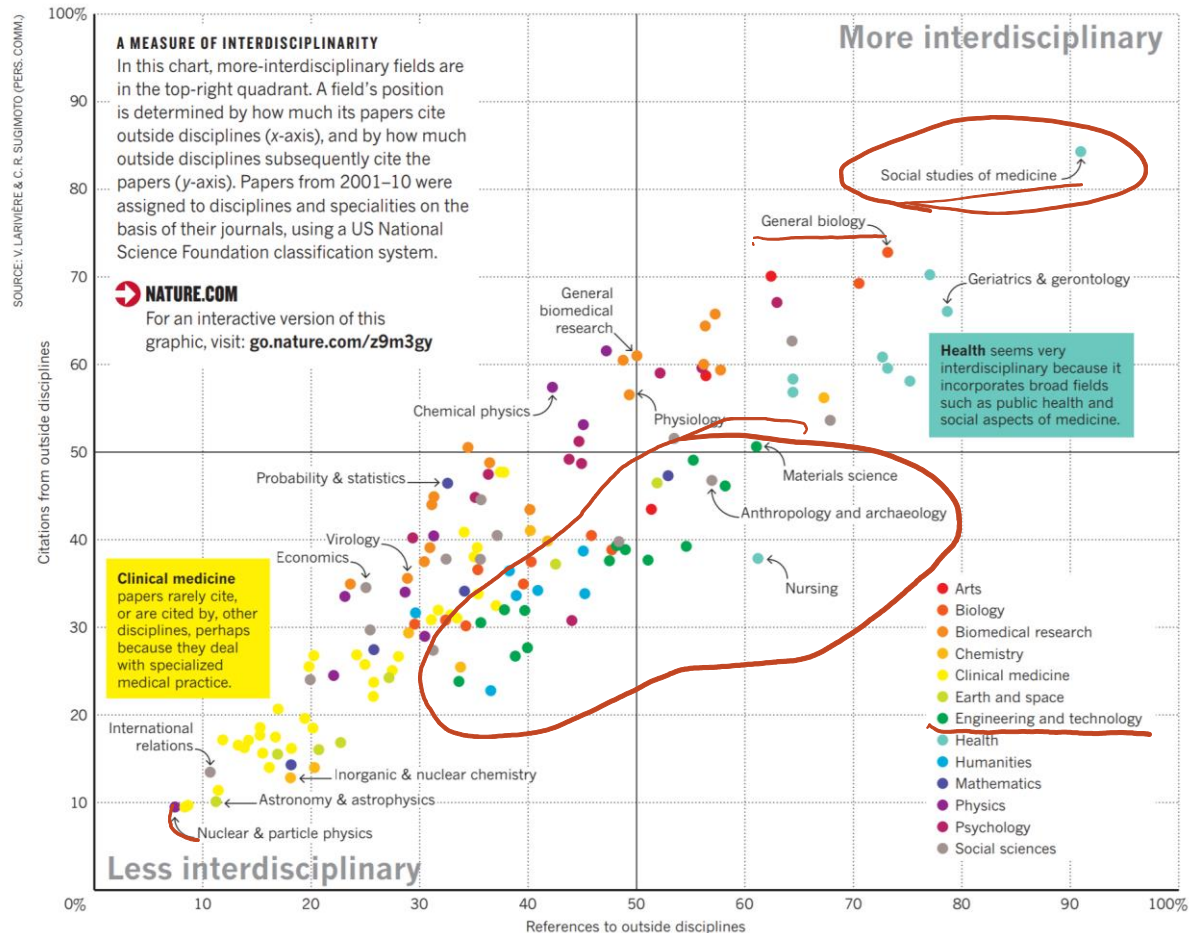
Citations increase as a paper's interdisciplinarity increases.



SOURCE: J. WANG ET AL. PLOS ONE 10, E0127298 (2015)

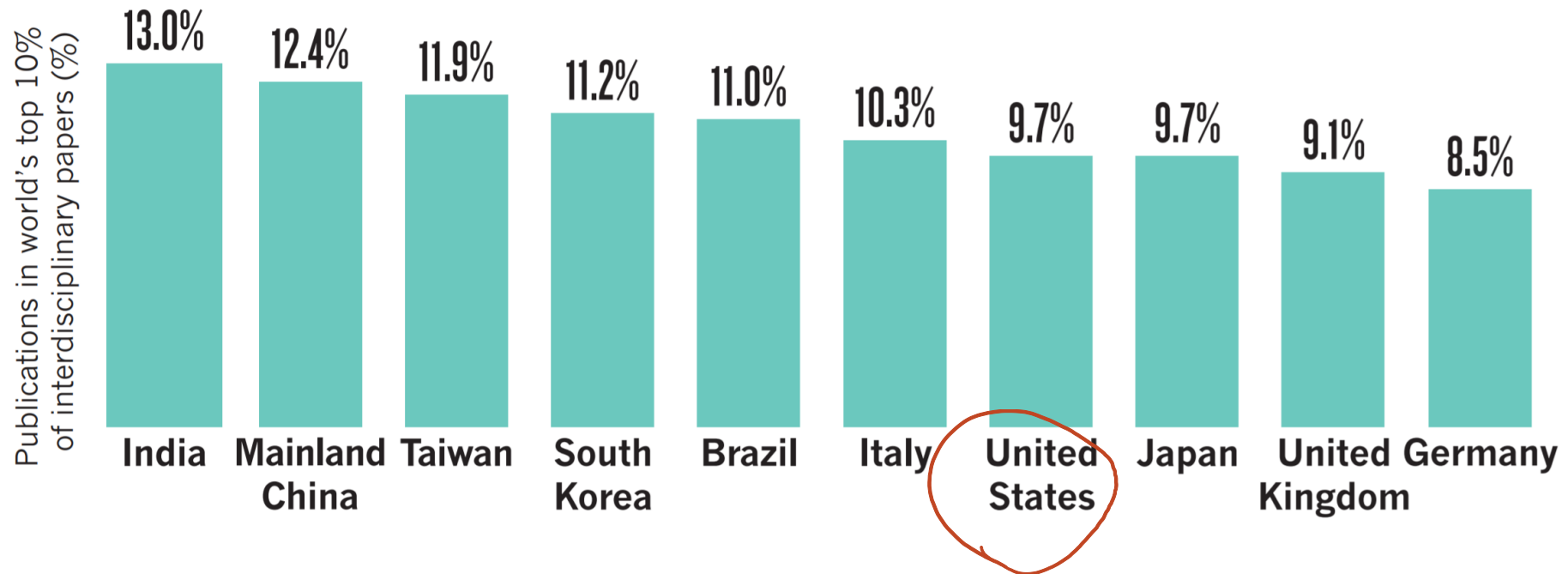
Trend

► Some fields are more interdisciplinary than others



Trend

- ▶ Some countries are more interdisciplinary than others



Outline

- ▶ Definition
- ▶ Significance
- ▶ Trend
- ▶ Key Challenges
- ▶ Towards Successful Interdisciplinary Research
- ▶ My Experience and Lessons Learned
- ▶ Q&A

Key Challenges

- What's my discipline? Learn a lot disciplines, but no in-depth understanding.
- Team members are reluctant to accept / appreciate methodologies / approaches in other disciplines
- Need methods to satisfy ^{"criteria" of} different disciplines
- Find "novelty" in all disciplines
- Different methodologies are hard to be combined

Key Challenges

- ▶ Take longer than conventional projects
- ▶ Lack of common language among team members

Key Challenges

► Practical side

- Hard to find a suitable venue for publication
- More expensive / Insufficient funding
- Hard for job search / promotion due to a lack of large research community
- Departments may worry that faculty members and their grants would be snatched away → limited support



Letter | Published: 29 June 2016

Interdisciplinary research has
consistently lower funding success

Lindell Bromham , Russell Dinnage & Xia Hua

Nature **534**, 684–687 (30 June 2016) | [Download Citation](#) 

Outline

- ▶ Definition
- ▶ Significance
- ▶ Trend
- ▶ Key Challenges
- ▶ Towards Successful Interdisciplinary Research
- ▶ My Experience and Lessons Learned
- ▶ Q&A

Towards Successful Interdisciplinary Research

Research problem: right problem that indeed needs multiple disciplines

► Important factors *with high impact*

► Environmental/institutional factors

*supportive (internal funding, climate)
incentivize such research*

► Team factors

*heterogeneity / different background
understanding / appreciation of other disciplines
Communication: build common language, effective communication / frequent*

► Individual characteristics of team members

*Friendly, Capable
Motivated, Commitment
Openness to uncertainty*

Towards Successful Interdisciplinary Research

► Important factors

► Environmental/institutional factors

- Explicit institutional commitment to interdisciplinarity and sufficient resources

► Team factors

- Communication: Overcome the language barrier and reduce the chance of misunderstanding
- Leadership: No hierarchy, or perceived hierarchy
- Trust: Must be confident that colleagues from other disciplines use equal academic rigor and scientific standing, even if the methods used in rival fields seem alien

► Individual characteristics of team members

- Commitment, flexibility, and being agreeable to work with

Towards Successful Interdisciplinary Research

- ▶ Ask questions without a compelling disciplinary basis
- ▶ Apply theories, concepts, or methods across disciplines with the intent of developing an overarching synthesis *common goal*
- ▶ A movement toward a coherence, unity, and simplicity of knowledge
- ▶ Teams work using a shared conceptual framework, drawing together discipline-specific theories, concepts, and approaches to address a common problem

Towards Successful Interdisciplinary Research

- ▶ Identify shared goals
- ▶ Get everyone on the same page
- ▶ Individuals are silos of techniques, bridge them together

My Experience

- ▶ Researchers working on Operations Research
 - ▶ Various optimization problems
- ▶ Forest Economist
 - ▶ Reduce illegal logging
- ▶ Psychologist and (Cognitive) Social Scientist
 - ▶ Understand and Learn Human Behavior Models
- ▶ Conservation Practitioner
 - ▶ Anti-poaching Effort
- ▶ Experts from Military Sectors
 - ▶ US Coast Guard
- ▶ Community/Municipality Leaders *peer-to-peer ridesharing*
 - ▶ Department of Human Services
 - ▶ Officer in charge of improving transportation for residents in Hulton Arbors
- ▶ Leaders from NGOs
 - ▶ 412FoodRescue

Lessons Learned (PAWS)

- ▶ First-hand immersion in the security environment of concern is critical to understanding the context and accelerating the development process
- ▶ Visualizing the model / solution ^{Interpretation} is important for communication and technology adaptation
- ▶ Minimizing the need for extra equipment/effort would further ease test / deployment in the field

Lessons Learned (Other)

Actively reach out

- ▶ Find the right collaborators
- ▶ Be prepared for the challenges
- ▶ Determine the common goal
- ▶ Overcome language barrier by patient communication / teaching
- ▶ Keep iterating with the domain experts
- ▶ Field evaluation

Great collaborators:

- 1) ^{true} expert in their field
- 2) open-minded for collaborators
- 3) committed ← funding agreement
- 4) pace of work

Right Incentives

Q&A

References

- ▶ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1955232/>
- ▶ <https://www.nature.com/articles/nature18315>
- ▶ <https://www.nature.com/news/interdisciplinarity-1.18295>
 - ▶ <https://www.nature.com/news/2015/150911/pdf/525306a.pdf>
- ▶ <https://onlinelibrary.wiley.com/doi/abs/10.1002/wics.200>

Backup Slides

Definition

- ▶ Three key definitional characteristics
 - ▶ The qualitative mode of research
 - ▶ Existence of a continuum of synthesis among disciplines
 - ▶ Desired outcome of the interdisciplinary research

Divergent Paradigms

▶ Divergent Paradigms

- ▶ Example: The methodologies of the physical and social sciences are primarily hypothesis driven and use experimentation and manipulation to achieve objectivism

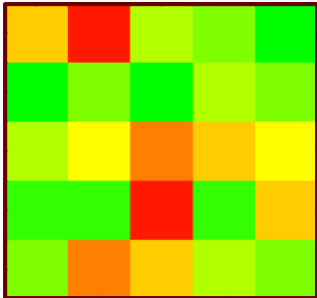
HOW CAN WE HELP



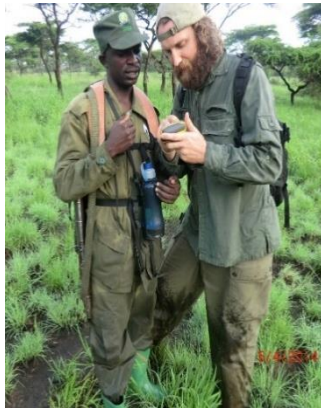
- ▶ “In most parks, ranger patrols are poorly planned, reactive rather than pro-active, and habitual in their deployment”
- ▶ PAWS (Protection Assistant for Wildlife Security)
 - ▶ Improve human patrol

PAWS OVERVIEW

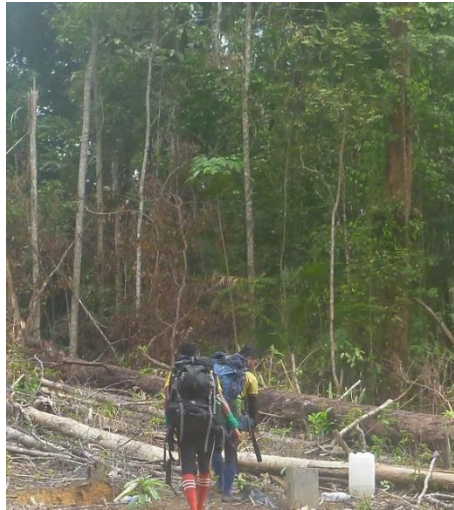
Proposed
(Yang et al. 14)



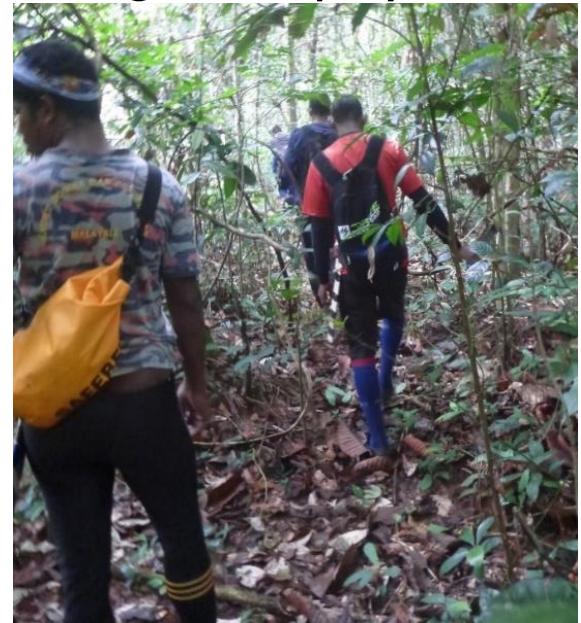
Uganda



1st test in Malaysia



Regular deployment



2013 Fall

2014 Spring

2014 Fall

2015 Fall



45/45

Rong Yang, Benjamin Ford, Milind Tambe, Andrew Lemieux. *Adaptive Resource Allocation for Wildlife Protection against Illegal Poachers*. AAMAS'14. 2/14/2016

GAME-THEORETIC REASONING

► Successful applications

Airports



2007

Flights



2009

Roads



2011

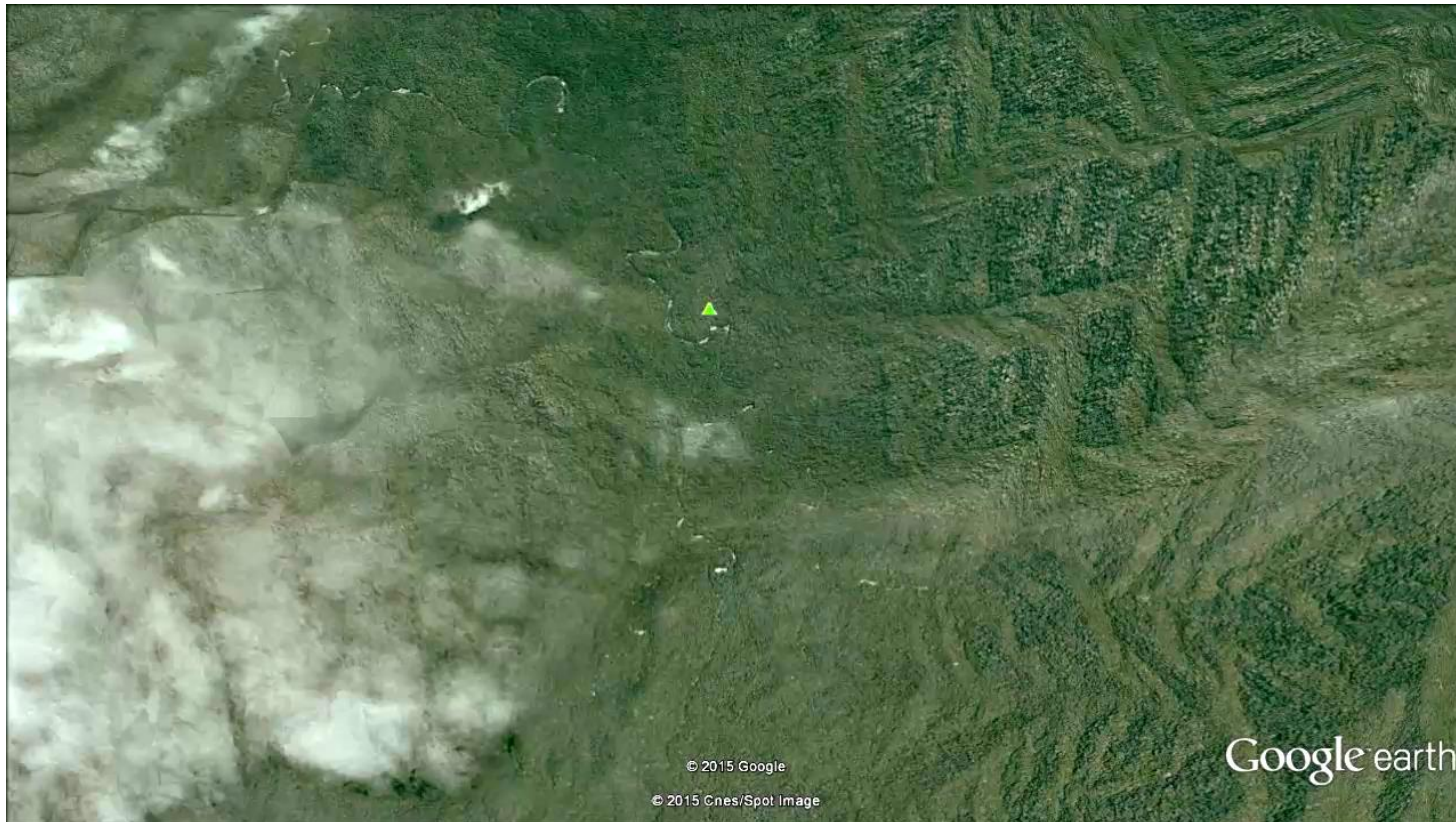
Ports



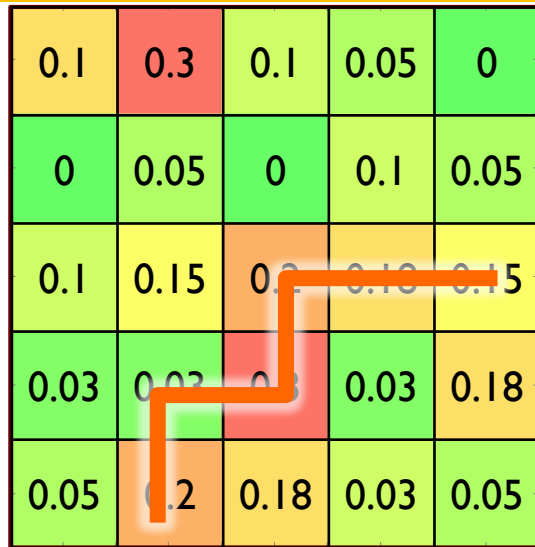
2012

ROUTE PLANNING

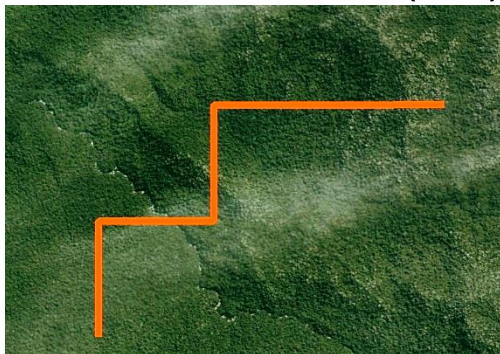
- ▶ Coverage probability $c \rightarrow$ route to take
- ▶ Second challenge: Route not compatible with terrain



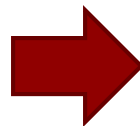
COMPLEX TOPOGRAPHICAL INFORMATION



Patrol Route (2D)

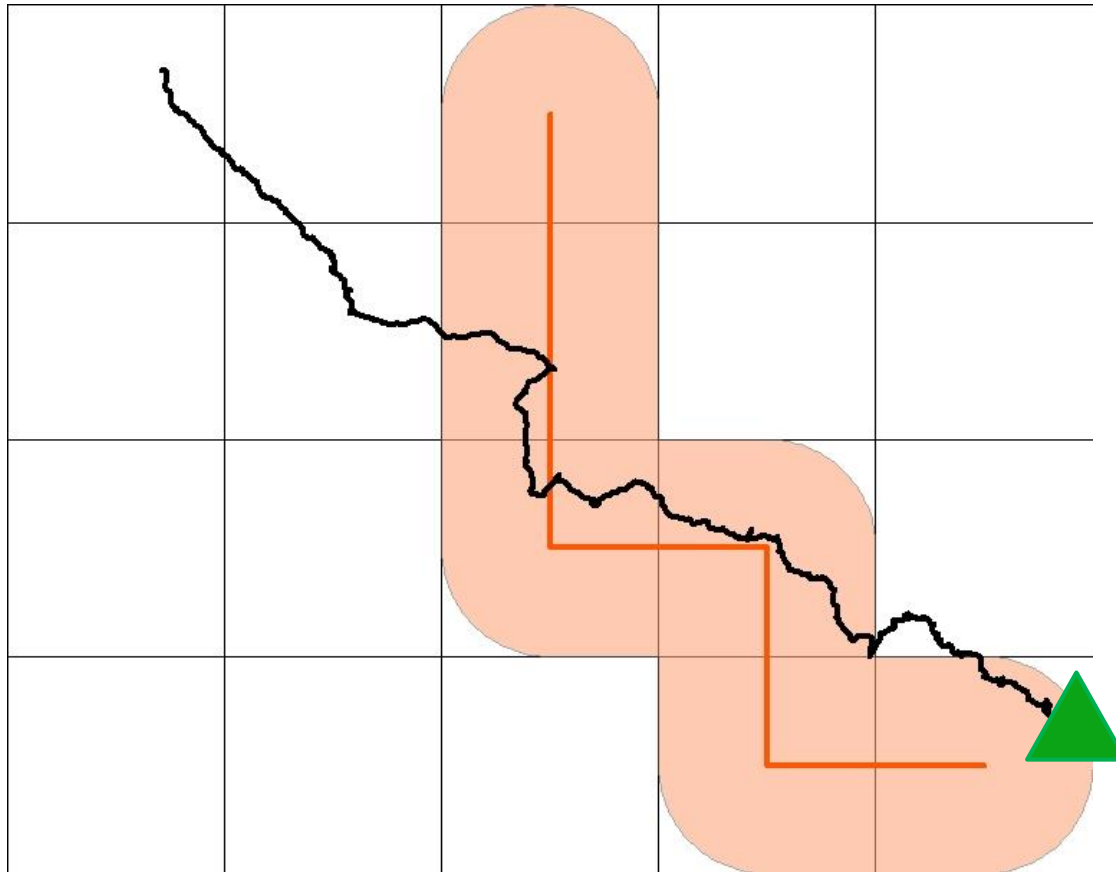


Patrol Route (3D)



FIRST TESTS

► Test in Malaysia



FIRST TESTS

► Test in Uganda



TRIAL PATROL IN THE FIELD

- ▶ 8-hour patrol in April 2015: patrolling is not easy!

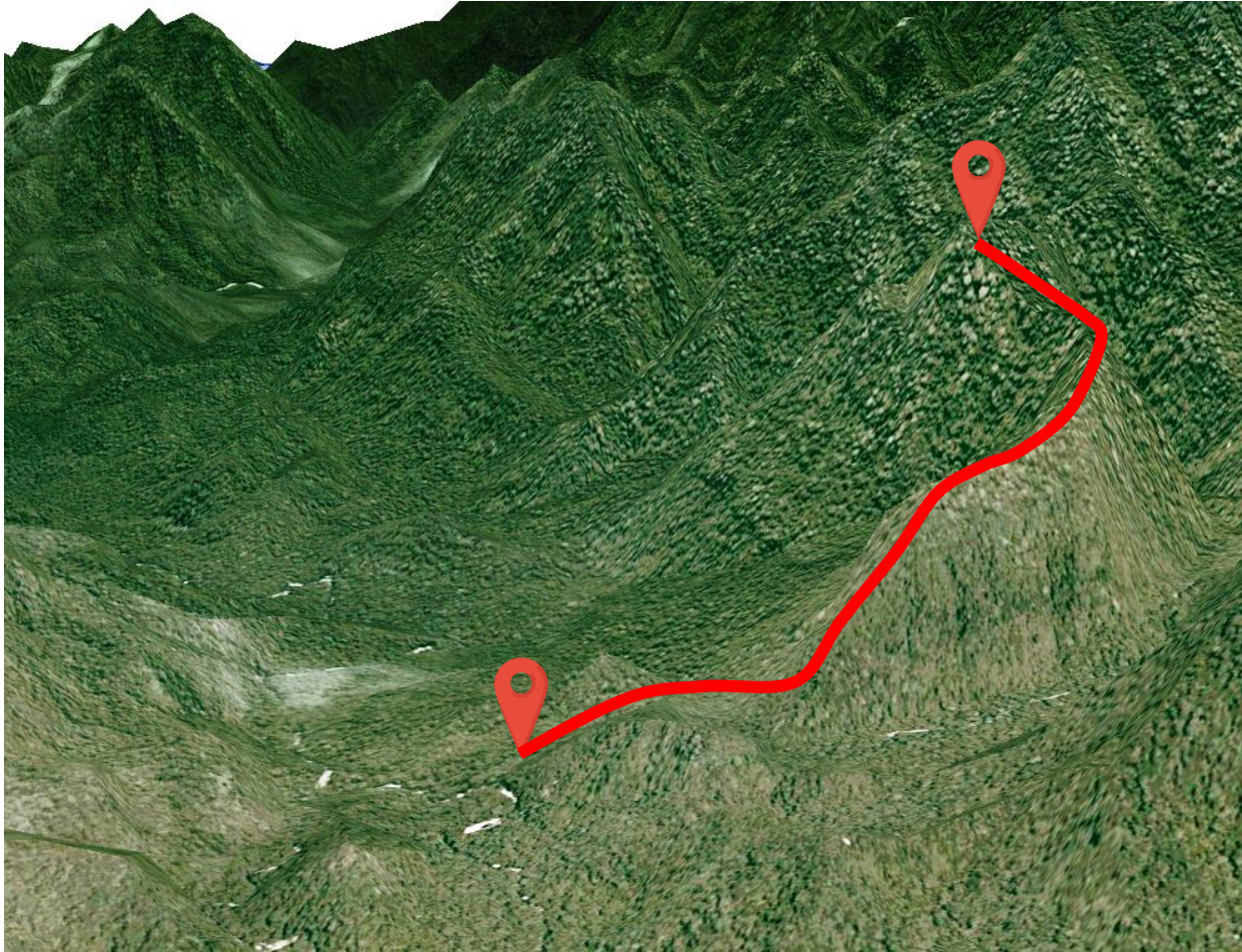


TRIAL PATROL IN THE FIELD

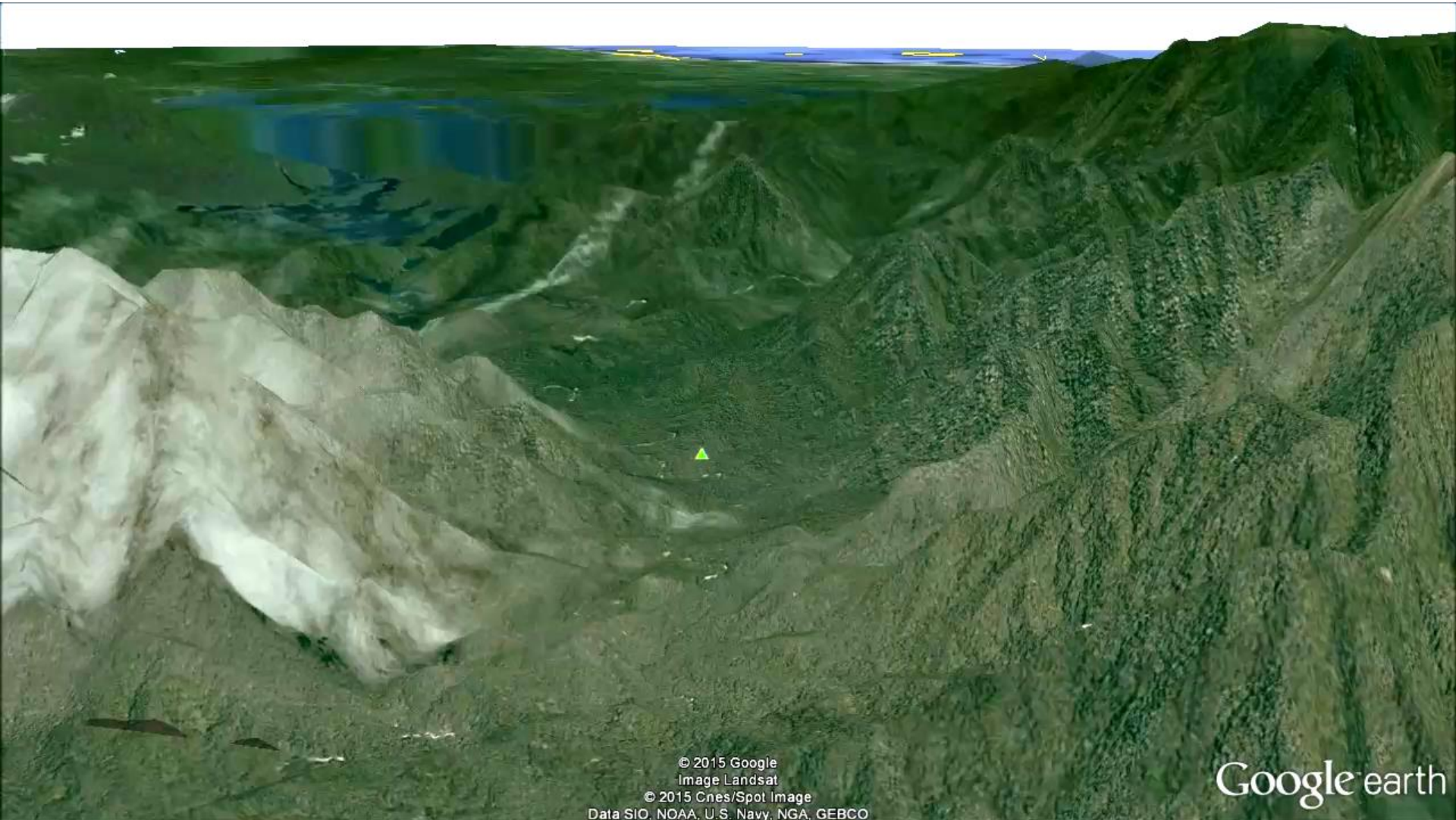


COMPLEX TOPOGRAPHICAL INFORMATION

- ▶ Terrain feature, e.g., ridgeline



ROUTE PLANNING

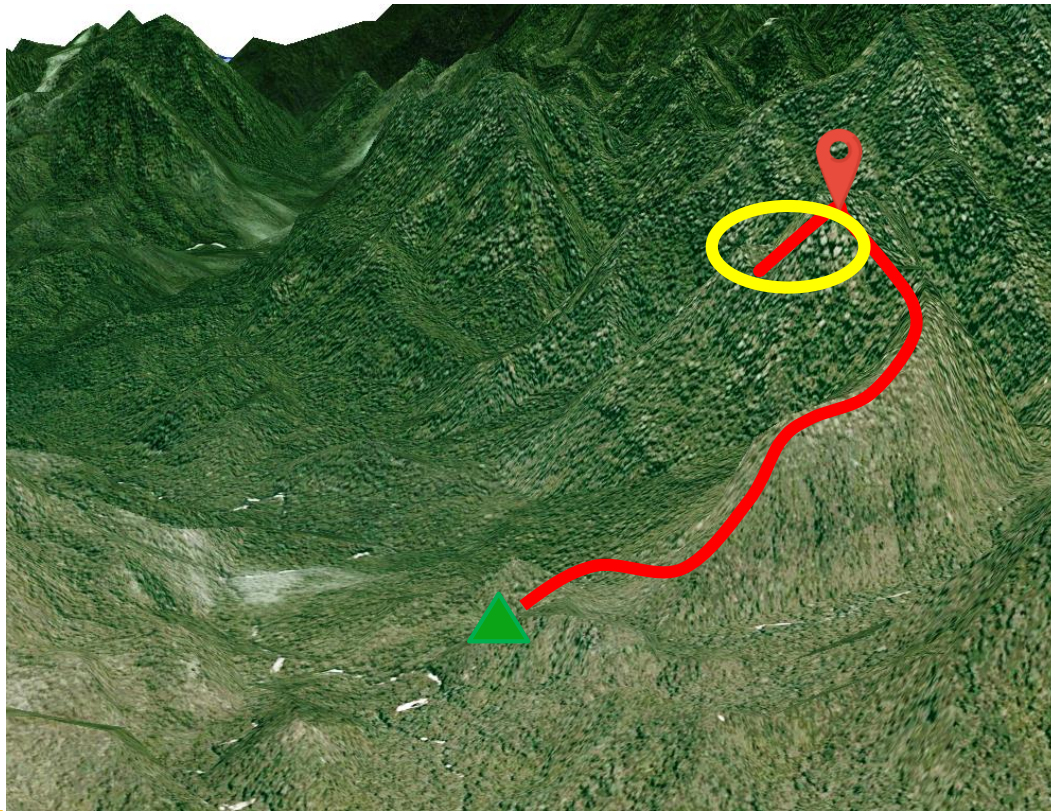


© 2015 Google
Image Landsat
© 2015 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth

BEFORE REAL-WORLD DEPLOYMENT

- ▶ Practical constraints (I)
 - ▶ Short downhill followed by returning uphill is annoying



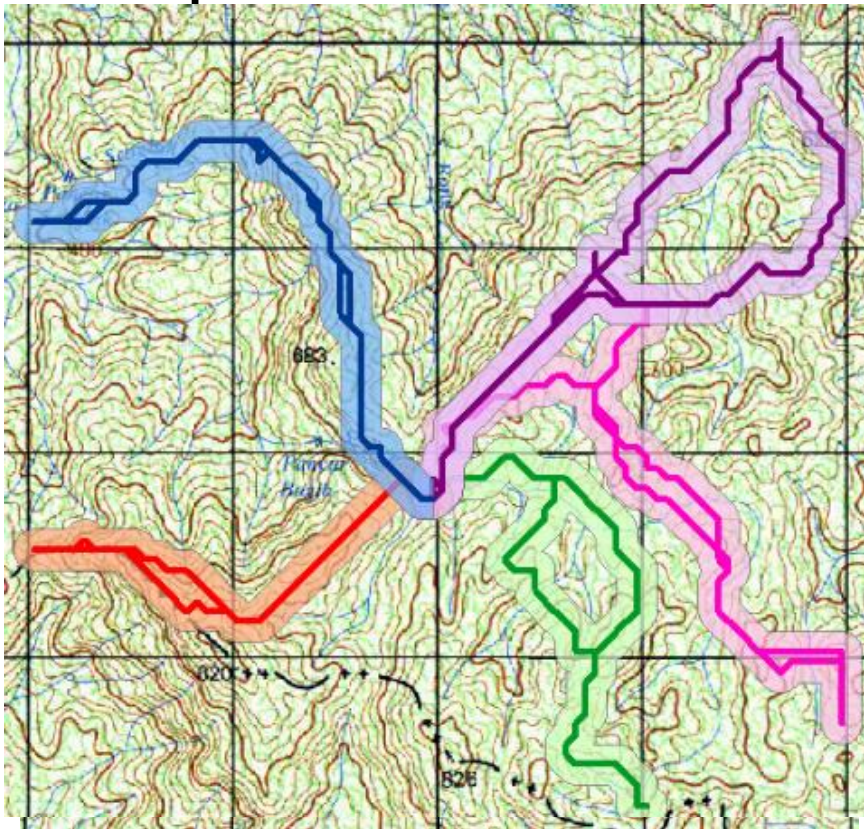
BEFORE REAL-WORLD DEPLOYMENT

- ▶ Practical constraints (II)
 - ▶ Patrol time = 5 hours = walking time + recording time



EXAMPLE OUTPUT OF PAWS

- ▶ 1 day patrol starting from a base camp
- ▶ Sample one route according to the probability every

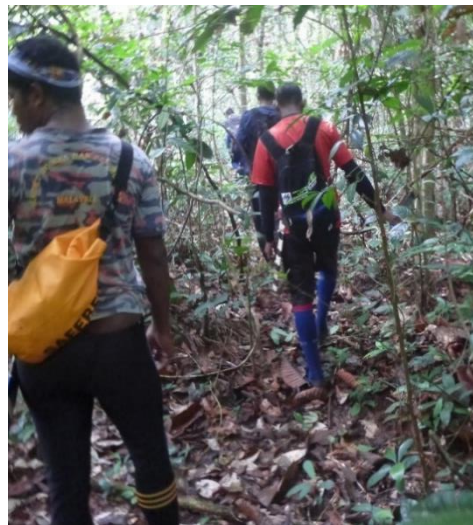
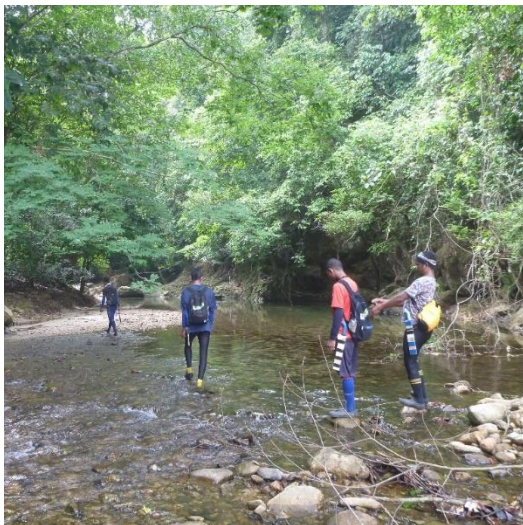


suggestedRoute 	Prob=0.58
suggestedRoute 	Prob=0.16
suggestedRoute 	Prob=0.12
suggestedRoute 	Prob=0.08
suggestedRoute 	Prob=0.06

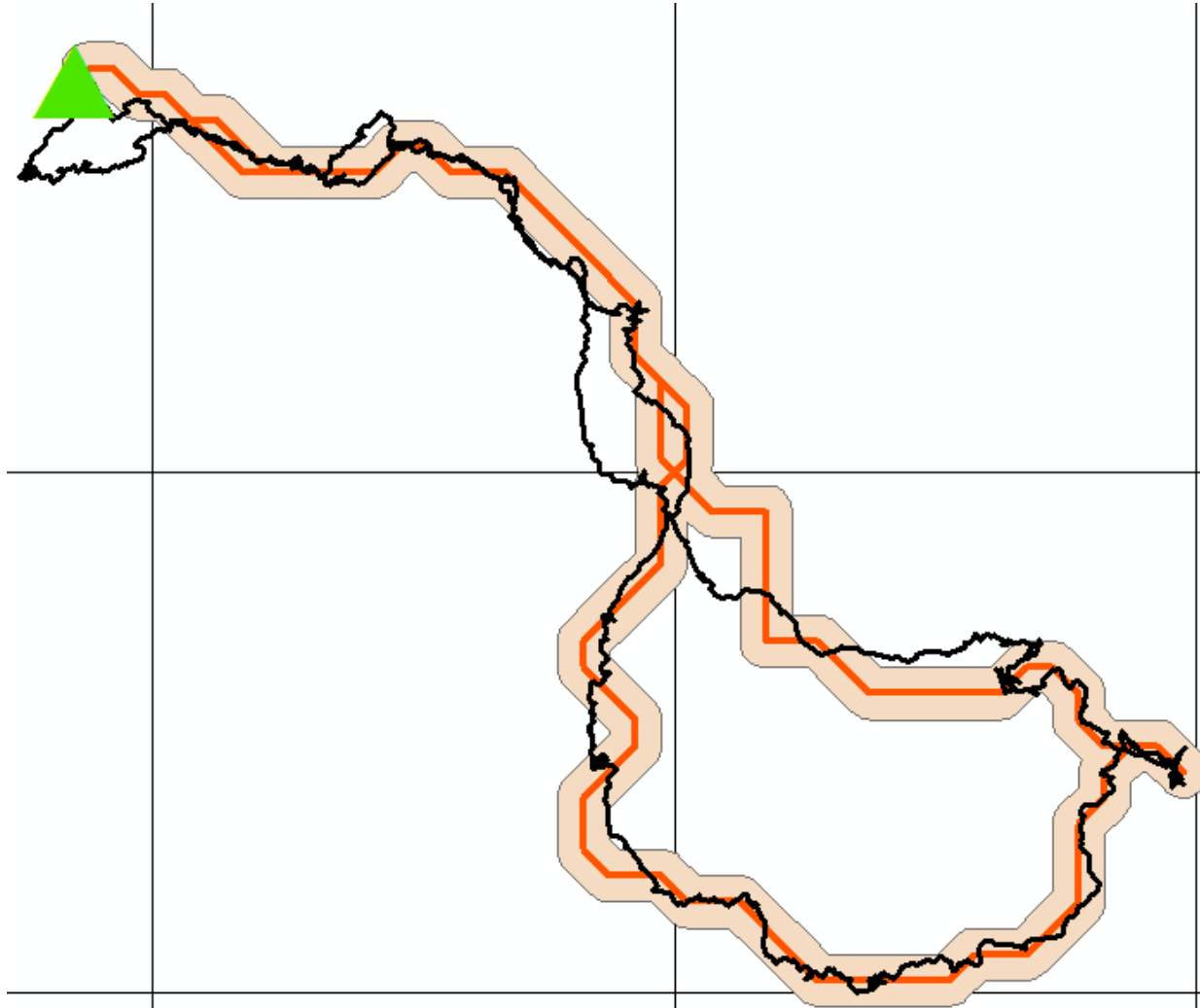
PAWS PATROLS IN THE FIELD

Basic Information of PAWS Patrols

Average Trip Length	4.67 Days
Average Number of Patrollers	5
Average Patrol Time Per Day	4.48 hours
Average Patrol Distance Per Day	9.29 km



PAWS PATROLS IN THE FIELD



PAWS PATROLS IN THE FIELD

Animal Footprint



Tree Mark



Camping Sign



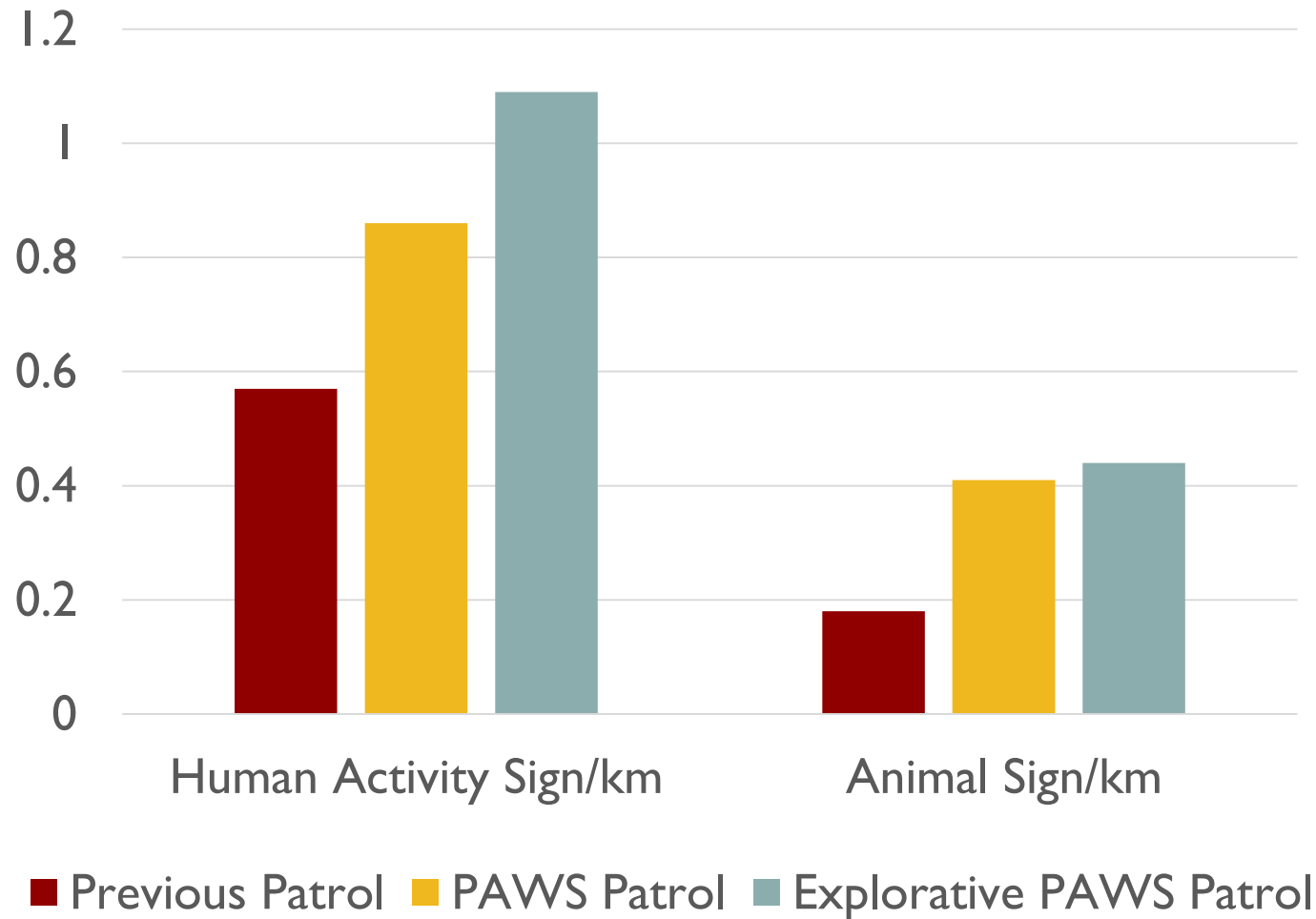
Tiger Sign



Lighter



PAWS PATROLS IN THE FIELD



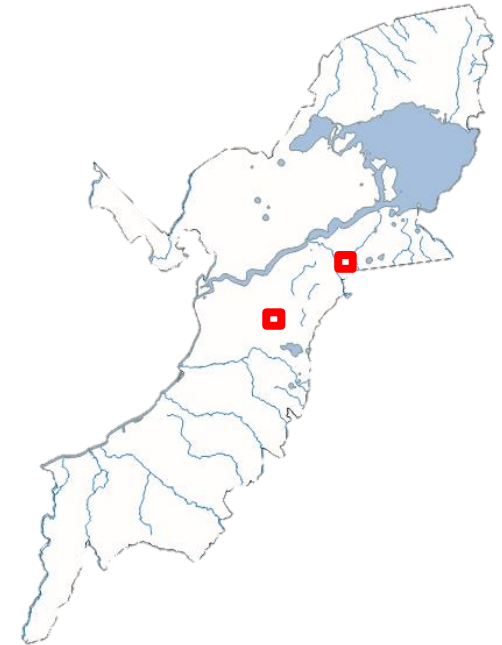
FUTURE DEPLOYMENT

- ▶ Queen Elizabeth National Park in Uganda
- ▶ Tested in Spring 2014
- ▶ PAWS with CAPTURE tool: Deploy later this year



One Month Field Test

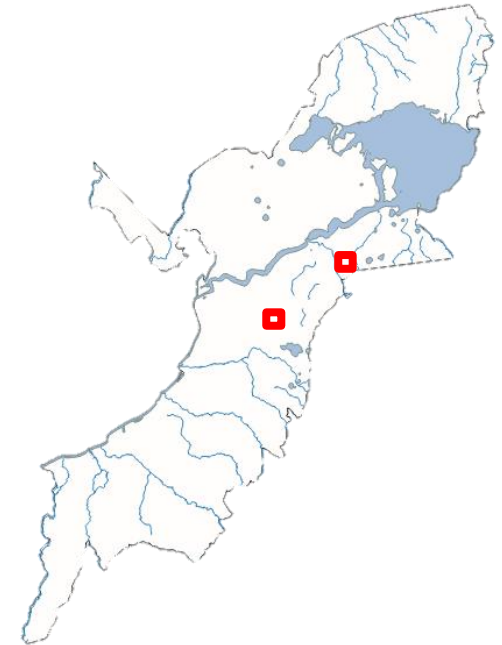
- ▶ Two 9-sq. km patrol areas
 - ▶ Infrequent patrols
 - ▶ Predicted hotspot
- ▶ Trespassing
 - ▶ 19 signs of litter, ashes, etc.
- ▶ Poached animals
 - ▶ 1 poached elephant
- ▶ Snaring
 - ▶ 1 active snare
 - ▶ 1 cache of 10 antelope snares
 - ▶ 1 roll of elephant snares
- ▶ Snaring hit rates
 - ▶ Outperform 91% of months



Historical Base Hit Rate	Our Hit Rate
Average: 0.73	3

Field Test I

- ▶ Two 9-sq. km patrol areas
 - ▶ Infrequent patrols
 - ▶ Predicted hotspot
- ▶ Trespassing
 - ▶ 19 signs of litter, ashes, etc.
- ▶ Poached animals
 - ▶ 1 poached elephant
- ▶ Snaring
 - ▶ 1 active snare
 - ▶ 1 cache of 10 antelope snares
 - ▶ 1 roll of elephant snares
- ▶ Snaring hit rates
 - ▶ Outperform 91% of months



Historical Base Hit Rate

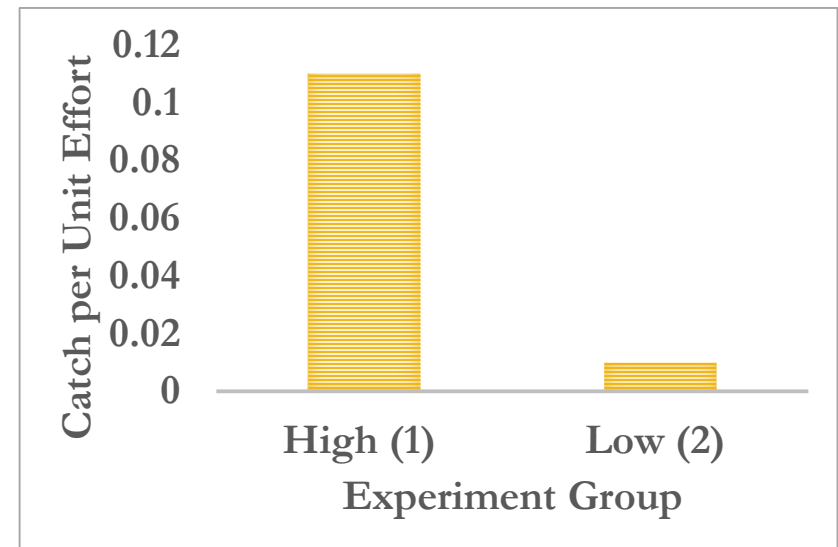
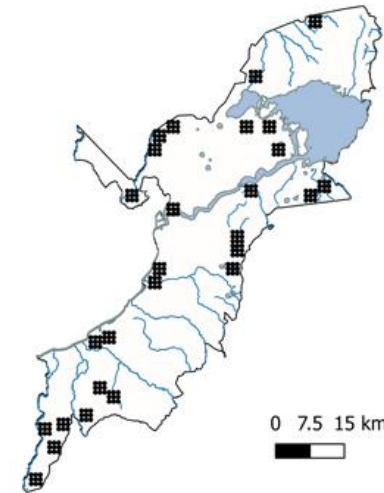
Our Hit Rate

Average: 0.73

3

Field Test 2

- ▶ 27 areas, 9-sq km each
- ▶ 2 experiment groups
 - ▶ HIGH: 5 areas
 - ▶ LOW: 22 areas
- ▶ 452 km patrolled in total
- ▶ Catch Per Unit Effort (CPUE)
 - ▶ Unit Effort = km walked
 - ▶ Historical CPUE: 0.03



PAWS: Protection Assistant for Wildlife Security

Uganda

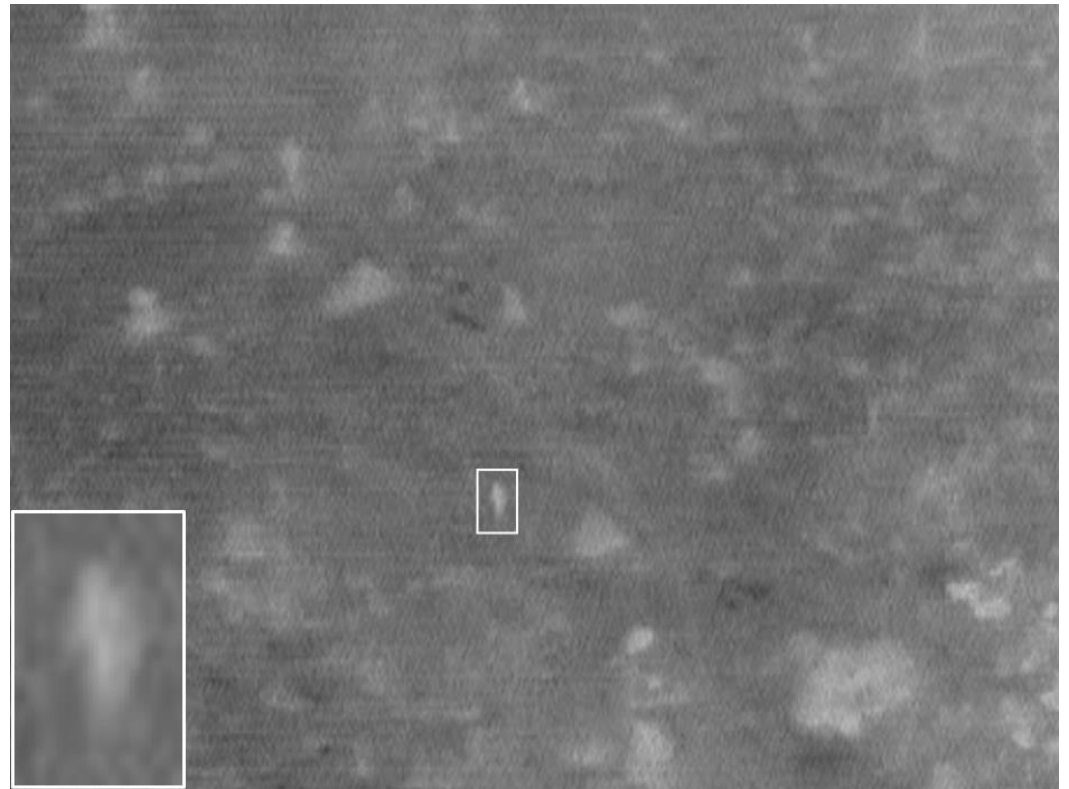


China



Future of PAWVS

- ▶ Detect poacher and wildlife in real time



Future of PAWS



SPOT Poachers in Action: Augmenting Conservation Drones with Automatic Detection in Near Real Time
Elizabeth Bondi, Fei Fang, Mark Hamilton, Debarun Kar, Donnell Dmello, Jongmoo Choi, Robert Hannaford, Arvind Iyer,
Lucas Joppa, Milind Tambe, Ram Nevatia
In IAAI-18: The Thirtieth Conference on Innovative Applications of Artificial Intelligence, February 2018