REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
27-01-2017	Final Report	1-Sep-2015 - 31-Aug-2016

4. TITLE AND SUBTITLE
Final Report: Learning and Inferring Networks from Incomplete Data

5a. CONTRACT NUMBER: W911NF-15-1-0546

5b. GRANT NUMBER:

5c. PROGRAM ELEMENT NUMBER: 611102

5d. PROJECT NUMBER:

5e. TASK NUMBER:

5f. WORK UNIT NUMBER:

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
66497-NS.4

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
In an increasingly interconnected world, information, goods, and even diseases propagate across explicit and implicit networks. Depending on the application, network edges can be used to represent different types of connections, from physical wires between computers to friendships among people. And in many situations, one can hope to learn the connections or other properties of a target network by examining whatever outputs of the network are observable, or by smartly intervening in the network and analyzing the results of the intervention. Designing algorithms for learning such networks is the goal of the proposed research.

15. SUBJECT TERMS
learning networks, graph structure, voting, maximum likelihood, incomplete data

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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					19b. TELEPHONE NUMBER: 312-413-9576

Report Title

Final Report: Learning and Inferring Networks from Incomplete Data

ABSTRACT

In an increasingly interconnected world, information, goods, and even diseases propagate across explicit and implicit networks. Depending on the application, network edges can be used to represent different types of connections, from physical wires between computers to friendships among people. And in many situations, one can hope to learn the connections or other properties of a target network by examining whatever outputs of the network are observable, or by smartly intervening in the network and analyzing the results of the intervention. Designing algorithms for learning such networks is the goal of the proposed research.
The army applications of this area are numerous and significant. Some examples of problems broadly covered by this proposal include reconstructing an adversary's networks from in- tercepted or publicly available communications, better understanding supply networks from their disruptions, or even discovering hidden influence structures after observing the votes or writings of politicians or other actors.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
01/27/2017	1	Sam Cole, Shmuel Friedland, Lev Reyzin. A Simple Spectral Algorithm for Recovering Planted Partitions, Special Matrices, ( ): . doi:
TOTAL:		**1**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper
TOTAL:	

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper
01/27/2017	2 Benjamin Fish, Yi Huang, Lev Reyzin. Recovering Social Networks by Observing Votes, 15th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2016). 09-MAY-16, Singapore. : ,
01/27/2017	3 Yi Huang, Mano Vikash Janardhanan, Lev Reyzin. Network Construction with Ordered Constraints, Algorithms and Data Structures Symposium (WADS 2017). 01-AUG-17, St. John's, Canada. : ,
TOTAL:	**2**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper
TOTAL:	

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received	Paper
TOTAL:	

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME PERCENT_SUPPORTED

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Total Number:

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This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

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The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

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Names of Personnel receiving masters degrees

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Total Number:

Names of personnel receiving PHDs

NAME

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Names of other research staff

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Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The results in this project include 1) algorithms for recovering social networks, 2) algorithms for recovering community structure in random graphs, and 3) algorithms for inferring social networks from ordered constraints. I summarize as follows.

1) In [1] we investigated how to reconstruct social networks from voting data. In particular, given a voting model that considers social network structure, we aim to find the network that best explains the agents' votes. We looked at two plausible voting models, one edge-centric and the other vertex-centric. For these models, we give algorithms and lower bounds, characterizing cases where network recovery is possible and where it is computationally difficult. We also tested our algorithms on United States Senate data.

Despite the similarity of the two models, we showed that their respective network recovery problems differ in complexity and involve distinct algorithmic challenges. Moreover, the networks produced when working under these models can also differ significantly. These theoretical and experimental results indicated that great care should be exercised when choosing a voting model for network recovery tasks.

2) In [2] we considered the planted partition model, in which n = ks vertices of a random graph are partitioned into k “clusters,” each of size s. Edges between vertices in the same cluster and different clusters were included with constant probability p and q, respectively (where 0 ? q < p ? 1). We gave an efficient algorithm that, with high probability, recovers the clustering as long as the cluster sizes are are least asymptotically sqrt(n). Our algorithm is based on projecting the graph's adjacency matrix onto the space spanned by its largest eigenvalues and using the result to recover one cluster at a time. Our algorithm is arguably simpler than previously known spectral algorithms: there is no need to randomly partition the vertices beforehand, and hence there is no messy “cleanup” step at the end. We also used a novel application of the Cauchy integral formula to prove its correctness. This work was solely theoretical.

3) In [3] we analyzed the problem of constructing a network by observing ordered connectivity constraints, which naturally result from observing twitter "retweets" among other information spreads. These ordered constraints are made to capture realistic properties of real-world problems that are not reflected in previous, more general models. We gave hardness of approximation results and nearly-matching upper bounds for the offline problem, and we study the online problem in both general graphs and restricted sub-classes. In the online problem, for general graphs, we gave exponentially better upper bounds than exist for algorithms for general connectivity problems. For the restricted classes of star and path networks we found algorithms with optimal competitive ratios. This work, again, was completely theoretical.

It is future work to implement and to test the algorithms in sections 2) and 3).

References

[1] Benjamin Fish, Yi Huang, Lev Reyzin. Recovering Social Networks by Observing Votes. In Proceedings of the 15th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2016)

[2] Sam Cole, Shmuel Friedland, Lev Reyzin. A Simple Spectral Algorithm for Recovering Planted Partitions. Manuscript, in submission to Special Matrices.

[3] Network Construction with Ordered Constraints. Yi Huang, Mano Vikash Janardhanan, and Lev Reyzin. Manuscript, in planned submission to WADS 2017.

Technology Transfer