IMPACTS OF HIGHLY CITED PAPER:

"Grid Coverage for Surveillance and Target Location in Distributed Sensor Networks, IEEE Trans. on Computers Vol 51 No. 12 Dec. 2002"

NUMBER OF CITATIONS

1000+

MOTIVATION

Grid coverage is a version of the point coverage problem. In this problem, we are given a 2D or 3D grid of points that are to be sensed. Sensor locations are restricted to these grid points and each grid point is to be covered by at-least q, $q \geq 1$, sensors (that is, we seek q-coverage). For sensing, we have t sensor types available. A sensor of type i costs c_i dollars and has a sensing range r_i. At most one sensor may be placed at a grid point. In this version of the point coverage problem, the sensors do not communicate with one another and are assumed to have a communication range that is large enough to reach the base station from any grid position. Thus, network connectivity is not an issue. The objective is to find the least cost sensor deployment that provides q-coverage.

FIRST IN THE LITERATURE

Prior to this work, the literature of distributed sensor networking has largely ignored the above sensor placement problem. Most prior work had concentrated exclusively on efficient sensor communication and sensor ion for a given sensor field architecture. However, as sensors are used in greater numbers for field operation, efficient deployment strategies become increasingly important. Related work on terrain model acquisition for motion planning has focused on the movement of a robot in an unexplored "sensor field". While knowledge of the terrain is vital for surveillance, it does not directly solve the sensor placement
Problem.

SUMMARY OF CONTRIBUTION

We formulate the q-coverage deployment problem as an ILP with $O(tn^2)$ variables and $O(tn^2)$ equations, where n is the number of grid points. For a large n, we propose a divide-and conquer "near-optimal" algorithm in which the base case (a small number of points) is solved optimally by using the ILP formulation.

IMPACT ON PHD DISSERTATIONS

In the area of sensor networks narrowly defined, this work is cited in over 44 PhD thesis:

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2. Cashbaugh, Jasmine. "Cluster Control of a Multi-Robot Tracking Network and Tracking Geometry Optimization." (2016).
3. Ramsden, Daryn. Optimization approaches to sensor placement problems. Diss. Rensselaer Polytechnic Institute, 2009.
4. Kavalapara, Rahul. "Energy-Efficient Fault Tolerant Coverage for Wireless Sensor Networks." (2010).
5. Jourdan, Damien. Wireless sensor network planning with application to UWB localization in GPS-denied environments. Diss. Massachusetts Institute of Technology, 2006.
6. Huang, Meng-chiang. "Collaborative Detection of Unauthorized Traversals in Mobile Sensor Networks." (2014).
7. Khalil, Issa. "Mitigation of Control and data traffic attacks in wireless ad-hoc and sensor networks." Purdue University(2007).
8. Dong, Shaoqiang. Node Placement, Routing and Localization Algorithms for Heterogeneous Wireless Sensor Networks. Diss. 2008.
9. Yonga, Franck Ulrich Yonga. Enabling Runtime Self-Coordination of Reconfigurable Embedded Smart Cameras in Distributed Networks. University of Arkansas, 2015.
10. Dewasurendra, Duminda A. Evidence filtering and its distributed implementation on grid sensor networks. University of Notre Dame, 2009.
11. Seetharaman, Sumathi. Self-organized scheduling of node activity in large-scale sensor networks. Diss. University of Cincinnati, 2004.
12. Bagheri, Majid. Efficient k-coverage algorithms for wireless sensor networks and their applications to early detection of forest fires. Diss. School of Computing Science-Simon Fraser University, 2007.
13. Nagilla, Praveen Kumar. Sensor coverage and actors relocation in wireless sensor and actor networks (WSAN):| optimization models and approximation algorithms. Diss. University of Missouri--Columbia, 2010.
14. Vlasenko, Iuliia. Deployment planning for location recognition in the Smart-Condo™: Simulation, empirical studies and sensor placement optimization. Diss. University of Alberta (Canada), 2013.
15. Marshall, Michael Brian. "A swarm intelligence approach to distributed mobile surveillance." (2005).
16. Zheng Shujun, "Indoor Positioning System Using Pyroelectric Infrared Sensors for Wireless Sensing Networks." China, (2013).

17. Yedavalli, Kiran Kumar. On location support and one-hop data collection in wireless sensor networks. University of Southern California, 2007.
18. Al-Omari, Safwan. Petra: Toward dependable and autonomic networked sensor systems. Diss. Wayne State University, 2009.
19. Deyab, Tamer Mohamed. Optimization of Sensors Deployment in a 3D-Environment under the Coverage, Connectivity and Energy Consumption Constraints. Diss. King Fahd University of Petroleum and Minerals (Saudi Arabia), 2011.
20. Yildiz, Enes. Providing multi-perspective coverage in wireless multimedia sensor networks. Southern Illinois University at Carbondale, 2011.
21. Eliş, Haluk. Terrain visibility and guarding problems. Diss. Bilkent University, 2017.
22. El-Rewini, Hesham, et al. "ON THE DEPLOYMENT OF MOBILE HETEROGENEOUS SENSORS IN CRITICAL INFRASTRUCTURE."
23. Wu, Xiaoling. Coverage-driven Energy-efficient Deployment and Self-organization in Sensor Networks. Diss. Thesis for the Degree of Doctor of Philosophy, Dept. Comput. Eng., Graduate School, Kyung Hee Univ., Seoul, Korea, 2008.
24. Watfa, Mohamed Khalil. Coverage issues in wireless sensor networks. Diss. 2006.
25. Xiang, Yun. "Mobile Sensor Network Design and Optimization for Air Quality Monitoring." (2014).
26. Ergen, Sinem Coleri. Wireless sensor networks: Energy efficiency, delay guarantee and fault tolerance. Diss. University of California, Berkeley, 2005.
27. Rocha, Bruno Filipe Ferreira Graça. Structural health monitoring of aircraft structures: development of a phased array system. Diss. 2010.
28. Ababnah, Ahmad A. Sensor deployment in detection networks-a control theoretic approach. Diss. Kansas State University, 2010.
29. Erande, Kaustubh Rajan. Design of a user driven real time asset tracking system using RFID in a healthcare environment. Oklahoma State University, 2008.
30. Das, Nibedita. Coverage and connectivity problems for sensor networks. Arizona State University, 2010.
31. Erickson, Lawrence H. Visibility analysis of landmark-based navigation. University of Illinois at Urbana-Champaign, 2014.
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33. Zhao, Jian. Camera planning and fusion in a heterogeneous camera network. University of Kentucky, 2012.
34. Fusco, Giordano. Coverage Optimization in Sensor and Cellular Networks. Diss. State University of New York at Stony Brook, 2013.
35. Ramadan, Rabie A. On the deployment of mobile heterogeneous sensors in critical infrastructure. Diss. Southern Methodist University, 2007.
36. Sanli, Hidayet Ozgur. Energy aware node scheduling and multiple target tracking with event miss-ratio assurances in wireless sensor networks. Arizona State University, 2007.

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38. Hays, Jacob. Control of Self-Reconfigurable Robot teams for sensor placement. Rochester Institute of Technology, 2010.
39. Khazaeni, Yasaman. An event-driven approach to control and optimization of multi-agent systems. Diss. Boston University, 2016.
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42. Golen, Erik F. Intelligent deployment strategies for passive underwater sensor networks. Rochester Institute of Technology, 2009.
43. Sumanasena, MG Buddika. A multidimensional systems approach to grid sensor networks. University of Notre Dame, 2012.
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INDUSTRY IMPACT: PATENTS

- 8019576: Method for placement of sensors for surveillance Issued: September 13, 2011. Assignee company: Telcordia http://www.patentgenius.com/patent/8019576.html

- 7688793: Wireless sensor node group affiliation method and apparatus Issued: March 30, 2010. Assignee company: Motorola http://www.patentgenius.com/patent/7688793.html

- 7,676,805 B2 Issued: March 9, 2012 Assigned to: Motorola

- 8131839 B2: Method and apparatus for resource assignment in a sensor network Issued: March 6, 2012 Assignee company: Motorola https://www.google.com/patents/US8131839

- https://www.google.ch/patents/WO2015132691A2?cl=en (Method for deploying sensors)

- Decentralized detection, localization, and tracking utilizing distributed sensors US 7480395 B2 January 2009 https://www.google.com/patents/US7480395

- Systems and methods for characterizing the coverage of ad hoc sensor networks US 7091902 B2 (Xerox Corporation) August 2006 https://www.google.com/patents/US20050134499

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DOCUMENTED IMPACT ON RESEARCH AT BOEING CORPORATION

Mattikalli, R. Fresnedo, R. Frank, P. Locke, S. Thunemann, Z. Optimal Sensor Selection and Placement for Perimeter Defense, 2007.

DOCUMENTED IMPACT ON RESEARCH AT DEPARTMENT OF DEFENSE

Capt. S. Hynes and N. S. Rowe, "Multi-Agent Simulation for Assessing Massive Sensor Deployment", Article at Naval Postgraduate School, 2004
http://www.www.dodccrp.org/events/2004_CCRTS/CD/papers/072.pdf

IMPACT ON NSF GRANTS

Several NSF grants were awarded to researchers who have built up on and leveraged the pioneering work on sensor deployment and minimalistic sensor networks. Here is a snapshot of some these grants:

- Award Number: CNS-1054935 ("CAREER: A Theoretical Foundation for Achieving Sustainability and Scalability in 3D Wireless Sensor Network Deployments")

- Award Number: CNS- 1152134 ("Optimal Surface Gateway Deployment for Underwater Acoustic Sensor Networks")

- Award Number: 0449309 ("Collaborative Signal and Information Processing in Sensor Networks")

- Award Number: CNS-1149611 ("SensorFly: Minimalistic Dynamic Sensing and Organization in Groups of Semi-Controllable Mobile Sensing Devices")