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#1569421039: *Localization from Incomplete Noisy Distance Measurements*

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Conference and *track*		**2011 IEEE International Symposium on Information Theory** - *2011 IEEE International Symposium on Information Theory*

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Presenter		presenter not specified
Registration		+
Category		Eligible for ISIT Student Paper Award
Title		*Localization from Incomplete Noisy Distance Measurements*

Abstract

"THIS PAPER IS ELIGIBLE FOR THE STUDENT PAPER AWARD" We consider the problem of positioning a cloud of points in the Euclidean space $\mathbb{R}^d$, from noisy measurements of a subset of pairwise distances. This task has applications in various areas, such as sensor network localizations, NMR spectroscopy of proteins, and molecular conformation. Also, it is closely related to dimensionality reduction problems and manifold learning, where the goal is to learn the underlying global geometry of a data set using measured local (or partial) metric information. Here we propose a reconstruction algorithm based on a semidefinite programming approach. For a random geometric graph model and uniformly bounded noise, we provide a precise characterization of the algorithm's performance: In the noiseless case, we find a radius r_0 beyond which the algorithm reconstructs the exact positions (up to rigid transformations). In the presence of noise, we obtain upper and lower bounds on the reconstruction error that match up to a factor that depends only on the dimension d, and the average degree of the nodes in the graph.

Keywords		Positioning, Localization, Semidefinite programming, Graph realization, Manifold learning

Topics		Detection and estimation; Signal processing
Session		The program is not yet visible (tpc)
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Review manuscript

Document (show)	Pages	File size	Changed	MD5	Similarity score
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Personal notes

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Reviews

You are a TPC member for this conference.

3 Reviews

Review 1 (Reviewer C)

Importance	Technical Level	Novelty	Presentation	Recommendation
Very Important (4)	Extremely high technical level (5)	Extremely Novel (5)	Good (4)	Strongly Recommend (5)

Strengths (What are the key strengths of this paper?)

Very clean problem, very nice solution.

Weaknesses (What are the major weaknesses of this paper?)

Some details are missing, deferred to the journal version.

Comments and Recommendation (Please give the reasoning for your overall recommendation and any additional comments you wish to add.)

This paper studies the problem of reconstructing locations of nodes in a d-dimensional random geometric graph RGG from noisy pairwise distance measurements between neighbors.

- one thing that is unclear is that an edge exists between two nodes if they are *actually* within r, but the given measurement is noisy, so if $\tilde{d}_{ij}$ is positive we already know something about the noise. This lack of clarity may confuse readers.

- is the constant C in Lemmas III.1 and III.2 the same? I assume not, but it is a little confusing.

- make sure to punctuate equations properly

- should laplacian be Laplacian?

- In the 5 pages that would appear in the proceedings, the definitions from the work on rigidity theory is given, but somehow the intuition is lost. I would recommend jettisoning a bit more of the proofs and providing a clear description of the connection between the two concepts to help motivate more why the algorithm works. This is in the line of the bottom of page 1 to page 2, but about the proof idea.

Student Paper Award (This paper is eligible for the student paper award. Do you think it would rank among the top ten papers out of the 500 submitted papers in that category? If so, explain why.)

Yes. This is an elegant solution to a nice problem. It is a bit deeper than a "cute" result, and opens a new connection to rigidity theory while solving a nicely posed and clear problem. Would that all students could develop such results.

Review 2 (Reviewer B)

Importance	Technical Level	Novelty	Presentation	Recommendation
Very Important (4)	Good technical level (4)	Very Novel (4)	Good (4)	Recommend (4)

Strengths (What are the key strengths of this paper?)

See below.

Weaknesses (What are the major weaknesses of this paper?)

See below.

Comments and Recommendation (Please give the reasoning for your overall recommendation and any additional comments you wish to add.)

This paper discusses performance bounds for an SDP-based localization algorithm. The localization problem that is dealt with basically is a multi-dimensional scaling (MDS) problem with incomplete and noisy distance measurements. The paper is well-written and the derived theoretical results are novel and of high value. However, next to the proofs, it would have been interesting to see some discussion of these new theorems. It is for instance not really clear at this point whether they make any sense in a practical context, but I guess this will be reported in their future work. I feel that it is also important to cite the work of Wolkowicz from the University of Waterloo. They also proposed an SDP-based algorithm to solve the MDS problem with incomplete measurements (see for instance A. Y. Alfakih, A. Khandani, and H. Wolkowicz, “Solving Euclidean distance matrix completion problems via semidefinite programming,” Journal on Computational Optimization and Applications, vol. 12, no. 1, pp. 13 – 30, 1999).

For TPC eyes only (Write here if you have comments you don't wish the author to see.)

Good paper ... should be accepted.

Student Paper Award (This paper is eligible for the student paper award. Do you think it would rank among the top ten papers out of the 500 submitted papers in that category? If so, explain why.)

Maybe not.

Review 3 (Reviewer E)

Importance	Technical Level	Novelty	Presentation	Recommendation
Very Important (4)	Extremely high technical level (5)	Very Novel (4)	Room for improvement (2)	Recommend (4)

Strengths (What are the key strengths of this paper?)

The paper develops theory that predicts conditions under which an MDS-SDP sensor localization algorithm will recover the sensor locations (up to rotation and translation) as a function of the threshold applied to the observed pairwise distance matrix between sensors. While the conditions are rather strict. To this reviewer's knowledge this is the first time that sharp results of this kind have been obtained for sensor localization. The paper is based on innovative application from random geometric graph theory.

Weaknesses (What are the major weaknesses of this paper?)

1. The paper is poorly written and organized. There are too many highly technical lemmas and propositions proved in inadequate detail. The authors inform the reader that details are given in a cited full paper. However this paper is in preparation and therefore not available.

2. The theory presented applies only to one algorithm, the MDS-SDP, and this algorithm is difficult to implement in a practical sensor network setting since it is centralized and not scalable . In particular, it depends on a global eigendecomposition of the (connected) pairwise distance matrix.

3. The theory in the paper relies heavily on the assumption of 1) bounded noise on pairwise sensor distance squared; 2) i.i.d. uniformly distributed positions; and 3) connectivity of the graph associated with the observed distance matrix. These conditions are rarely satisfied in practice so the engineering utility of the results is called into question.

4. The paper is very dense technically which makes it hard to read and navigate. A roadmap to these many interconnecting results followed by a numerical example would have been helpful.

Comments and Recommendation (Please give the reasoning for your overall recommendation and any additional comments you wish to add.)

The paper describes a novel approach to analysis of performance for a spectral sensor localization algorithm. While the assumptions are rather stringent and the proposed algorithm is not practical in large communications limited networks the novelty is sufficient to justify acceptance. To enhance impact of their work I strongly suggest that the authors try and extend their analysis to embedded distributed sensor localization algorithms like the dwMDS algorithm of Costa etal, 2006 [1]. I think that the random euclidean graphs machinery is sufficient for such an analysis, except that, as the dwMDS algorithm is iterative, an addiitonal (bounded) function approximation error would need to be included.

[1] J. Costa, N. Patwari and A. O. Hero, "Distributed weighted-multidimensional scaling with adaptive weighting for node localization in sensor networks," ACM Journal on Sensor Networking. vol. 2, No. 1, pp 39-64, Feb. 2006

Student Paper Award (This paper is eligible for the student paper award. Do you think it would rank among the top ten papers out of the 500 submitted papers in that category? If so, explain why.)

No. While the results are interesting it is not sufficiently well written.

1 Summary review by TPC member

Review 1 (Reviewer A)

TPC recommendation

Accept (4)

TPC Recommendation Justification (Please give a justification for your recommendation, especially if the review scores vary widely or your recommendation differs significantly from those of the reviewers.)

reviewers are consistent.

Student Paper Award (This paper is eligible for the student paper award. The TPC needs to identify 10-15 semifinalists for the award from among the 500 submitted eligible papers. Later the IT Society Awards committee will select up to three winners. If you think this paper is worthy of the award, please send a one page nomination to the TPC cochairs at isit2011@eng.tau.ac.il with "STUDENT AWARD NOMINATION" in the subject header. The TPC co-chairs and IT Society Awards committee will have access to the papers, reviews (including your TPC summary review) and the nominations of the finalists. (You need not write anything in the box here.))

so far this is the strongest student paper in my collection -- will review once all of the papers have been assessed.

Discussion

Not a reviewer.
Apr 16, 2011
04:23

A TPC MEMBER SUBMITTED THE FOLLOWING NOMINATION OF THIS PAPER FOR THE STUDENT PAPER AWARD:
Localization in networks is a well-studied problem, especially in sensor networks, where many heuristic and non-heuristic algorithms have been proposed. However, an information-theoretic approach to the problem has been missing for some time now. What can information theory say about this problem? It can shed light on what the fundamental problem to be solved might be, and it can provide a ``clean'' characterization of what is and is not possible for this problem. This paper provides both. The main results are for a random geometric graph $G(n,r)$ with n nodes distributed in the unit hypercube of dimension d centered at the origin. Two nodes are connected if the distance between them is less than r. The algorithm is given noisy measurements $\tilde{d}_{ij}$ between pairs of connected nodes, where the noise is bounded but possibly adversarial. From the noisy measurements, the goals is to estimate the node positions. The authors then propose a simple semidefinite program (SDP) to accomplish this, noting that the covariance of the node's positions is a low-rank matrix. They show upper and lower bounds on the error of their estimate, and furthermore show that if the connectivity radius r is sufficiently large, then their method returns the exact node positions up to rigid transformations.

The key to understanding this problem is the connection between rigidity theory and the localization problem. When they describe this connection, the relevance is apparent. Using these tools and some spectral calculations they can derive the bounds for the performance of their algorithm. The paper is of course too short to contain the full argument. However, I believe the author's contribution is both novel and elegant, and makes a nice connection between what seems to be a wireless communication network problem and work in physics. The solution they provide is centralized, so this does not end the story, of course. But the authors have made a commendable start at understanding the fundamental limits of this fundamental problem.