The Final Oral Examination
for the Degree of

DOCTOR OF PHILOSOPHY
(Department of Electrical and Computer Engineering)

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2011                      Amirkabir University of Technology                   MASc

“Blind Received Signal Strength Difference Based Source Localization with System Parameter Error and Sensor Position Uncertainty”

Monday, August, 25, 2014
10:30 A.M.
Engineering Office Wing, room 430

Supervisory Committee:
Dr. T. Aaron Gulliver, Department of Electrical and Computer Engineering, UVic (Supervisor)
Dr. Fayez Gebali, Department of Electrical and Computer Engineering, UVic (Member)
Dr. George Tzanetakis, Department of Computer Science, UVic (Outside Member)

External Examiner:
Dr. Payman Arabshahi, Faculty of Electrical Engineering, University of Washington

Chair of Oral Examination:
Dr. Faoruk Nathoo, Department of Mathematics and Statistics, UVic
Abstract

Passive source localization in wireless sensor network (WSN) is an important field of research with numerous applications in signal processing and wireless communications. One purpose of a WSN is to determine the position of a signal emitted from a source. This position is then estimated based on received noisy measurements from sensors (anchor nodes) that are distributed over a geographical area. In most cases, the sensor positions are assumed to be known exactly, which is not always reasonable. Even if the sensor positions are measured initially, they can change over time.

Due to the sensitivity of source location estimation accuracy with respect to the a priori sensor position information, the source location estimates obtained can vary significantly regardless of the localization method used. Therefore, the sensor position uncertainty should be considered to obtain accurate estimates. Among the many localization approaches, signal strength based methods have the advantages of low cost and simple implementation. The received signal energy mainly depends on the transmitted power and path loss exponent which are often unknown in practical scenarios. In this dissertation, three received signal strength difference (RSSD) based methods are presented to localize a source with unknown transmit power. A nonlinear RSSD-based model is formulated for systems perturbed by noise.

First, an effective low complexity constrained weighted least squares (CWLS) technique in the presence of sensor uncertainty is derived to obtain a least squares initial estimate (LSIE) of the source location. Then, this estimate is improved using a computationally efficient Newton method.

The Cramer-Rao lower bound (CRLB) is derived to determine the effect of sensor location uncertainties on the source location estimate. Results are presented which show that the proposed method achieves the CRLB when the SNR is sufficiently high. Least squares (LS) based methods are typically used to obtain the location estimate that minimizes the data vector error instead of directly minimizing the unknown parameter estimation error. This can result in poor performance, particularly in noisy environments, due to bias and variance in the location estimate. Thus, an efficient two stage estimator is proposed here.

First, a minimax optimization problem is developed to minimize the mean square error (MSE) of the proposed RSSD based model. Then semidefinite relaxation is employed to transform this nonconvex and nonlinear problem into a convex optimization problem. This can be solved efficiently to obtain the optimal solution of the corresponding semidefinite programming (SDP) problem. Performance results are presented which confirm the efficiency of the proposed method which achieves the CRLB.

Finally, an extended total least squares (ETLS) method is developed for blind localization which considers perturbations in the system parameters as well as the constraints imposed by the relation between the observation matrix and data vector. The corresponding nonlinear and nonconvex RSSD-based localization problem is then transformed to an ETLS problem with fewer constraints. This is transformed to a convex semidefinite programming (SDP) problem using relaxation. The proposed ETLS-SDP method is extended to the case with an unknown path loss exponent. The mean squared error and corresponding CRLB are derived as a performance benchmark. Performance results are presented which show that the RSSD-based ETLS-SDP method attains the CRLB for a sufficiently large signal to noise ratio (SNR).
Awards, Scholarships, Fellowships

2014 – Teaching Excellence Award, University of Victoria
2014 – Paper Award IEEE Ocean Conf., Newfoundland
2013 – Outstanding Graduate Award, University of Victoria
2013 – IEEE Ocean Engineering Scholarship
2013 – Teaching Excellence Award, University of Victoria
2012 – EEE OCEAN Engineering Scholarship
2014 – Graduate fellowships, University of Victoria

Presentations


Publications


