Intelligent Systems, Robotics and Control (ISRC)

The ISRC portion of the MS Written Comprehensive Exam will contain two exam problems, one from **275A** and one from **276A.** A student is required to ***choose one*** problem and answer it. Please see respective study topics below.

If you choose the problem based on 275A (Parameter Estimation I), the required materials are the class notes and assigned books:

- *Fundamentals of Statistical Signal Processing: Estimation Theory*, S.M. Kay

The materials to be covered are:

(1) Minimum Variance Unbiased Estimation:
   a) Minimum Variance Criterion
   b) Existence of the MVUE
   c) Vector Parameters

(2) Cramer-Rao Lower Bound
   a) CRLB in Gaussian White Noise
   b) Transformation of Parameters
   c) Asymptotic CRLB for WSS Gaussian Processes

(3) General MVUE
   a) Sufficient Statistics
   b) Neyman-Fisher Factorization
   c) Sufficient Statistics and the MVUE

(4) Best Linear Unbiased Estimates
   a) Linear Models
   b) Finding the BLUE

(4) Maximum Likelihood Estimation
   a) Properties of the MLE
   b) Extension to a vector parameter
   c) Asymptotic MLE

(4) Least Squares Estimation
   a) Linear LSE
   b) Geometric Interpretation
   c) Sequential LSE
   d) Constrained LSE

If you choose the problem based on 276A (Sensing and Estimation in Robotics), the required materials are the class notes and assigned books:

- https://natanaso.github.io/ece276a/schedule.html

The following books are recommended but not required:

- Probabilistic Robotics: Thrun, Burgard & Fox
- An Invitation to 3-D Vision: Ma, Kosecka, Soatto & Sastry

The materials to be covered are:

(1) **Background: Linear Algebra & Probability Theory:**
a) Vectors: vector space, basis, dimension, norm, inner product
b) Matrices: null space, range, rank, norm, trace, determinant, inverse, eigenvalues, eigenvectors, quadratic forms, positive semidefinite matrices
c) Matrix inversion lemma, square completion, matrix calculus, matrix exponential properties
d) Probability space, random variable, CDF, pdf, expectation, variance, change of density, convolution, marginal, conditional, total probability, Bayes rule, independence

(2) **Supervised Learning:**
a) Generative vs discriminative models, MLE vs MAP
b) Linear and ridge regression
c) Logistic regression
d) Naive Bayes, Gaussian discriminant analysis, MLE parameters

(3) **Expectation Maximization:**
a) Membership probabilities
b) Local maxima of data log likelihood
c) Jensen's inequality, auxiliary function
d) K-means and EM algorithm

(4) **Rigid Body Motion:**
a) SO(3) group
b) Cross product, hat map, so(3)
c) Rotation dynamics, exponential map, Rodrigues formula
d) Quaternions
e) SE(3), "smart" plus and minus

(5) **Bayes Filtering:**
a) Bayes filter prediction and update
b) Kalman filter, extended and unscented Kalman filter
c) Gaussian mixture filter, particle filter, resampling

(6) **Motion and Observation Models:**
a) Differential drive and tricycle model

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b) Relative position, range, bearing models
c) Lidar model, occupancy grid, log-odds
d) Color spaces, camera model: intrinsics, extrinsics, projection
e) Corner features, image gradients, brightness constancy constraint, feature tracking and optical flow algorithms
f) RANSAC, Hough transform

(7) **Hidden Markov Models:**
a) Forward-backward procedure
b) Viterbi Decoding
c) Baum-Welch Algorithm