**Department of Mathematics**
**Indian Institute of Technology Delhi**
**MTL 799: Mathematical Analysis in Learning Theory**
**Course information**

**Course coordinator:** S. Sivananthan

**Course contents:**
Review: Normed linear space, Banach space, Hilbert space, Orthonormal basis, Projection theorem, Dual spaces, Riesz representation theorem, Bounded linear operators, Compact operators, Spectral theorem for self-adjoint compact operators

Reproducing Kernel Hilbert space (RKHS), Positive definite functions, Feature maps, Gaussian Kernel and their RKHSs, Mercer's theorem, The elements of statistical learning theory, Probabilistic inequalities, Tikhonov-type regularization, general regularization in Hilbert space, Representer theorem, Convergence analysis of empirical risk minimization, Adaptive regularization parameter choice rules

Approximation by trigonometric polynomials, Localized kernel approximations, Neural Networks, RBF neural networks, universal approximation, Convergence analysis of neural networks, Analysis of Deep vs Shallow, Universality of deep convolution neural networks, Generative adversarial nets and convergence analysis

**References Books:**

1. Bernhard Schölkopf and Alexander J. Smola, Learning with Kernels Support Vector Machines, Regularization, Optimization, and Beyond, MIT Press, 2002.
2. F. Cucker and D. Zhou, Learning Theory: An Approximation Theory Viewpoint, Cambridge University Press, 2007.
3. S. Lu, S.V. Pereverzev, Regularization Theory for Ill-posed problems, De Gruyter, 2013.
4. I. Steinwart and A. Christmann, Support Vector Machines, Springer, 2008.


**Selected reference Papers:**

1. F. Cucker and S. Smale, On the mathematical foundations of learning, Bulletin of the American Mathematical Society, Vol 39(1), 1--49, 2002.
2. E. De Vito, S. Pereverzyev, and L. Rosasco, Adaptive Kernel Methods Using the Balancing Principle, Found Comput Math., Vol 10, 455--479, 2010.
3. H.N. Mhaskar and T. Poggio, An analysis of training and generalization errors in shallow and deep networks, Neural Networks, Vol 121, 229--241, 2020.
4. T. Poggio and S. Smale, The Mathematics of Learning: Dealing with Data, Notice of the AMS, Vol 5 (5), 537-544, 2003. https://www.ams.org/notices/200305/fea-smale.pdf
5. D. Zhou, Universality of deep convolutional neural networks, Appl. Comput. Harmon. Anal., Vol 48, 787--794, 2020.


**Grading Policy:**
One minor examination - 20%
Three assignments - 30%
One viva - 20%
One major examination - 30%