

Multiple Kernel Learning and the SMO Algorithm

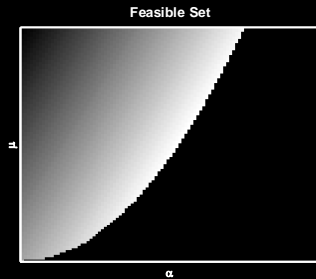
S. V. N. Vishwanathan, Zhaonan Sun, Nawanol Theera-Ampornpunt
Purdue University

Manik Varma
Microsoft Research India

Presented by Manik Varma

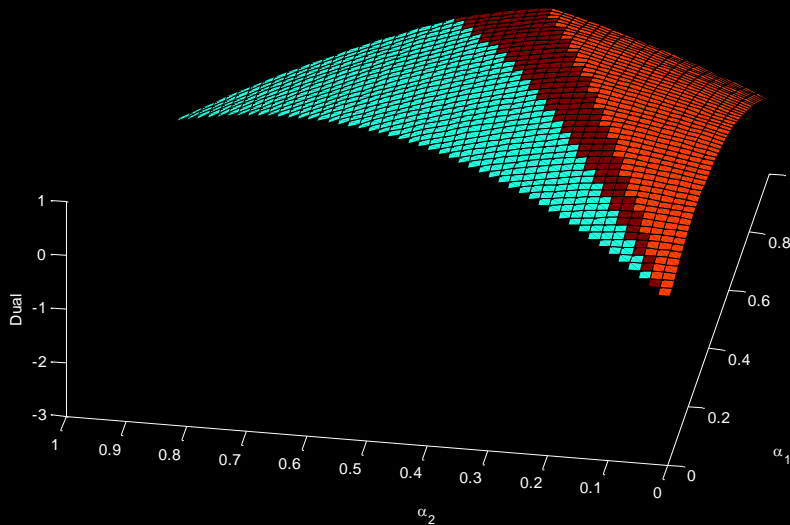
Multiple Kernel Learning

- MKL objective: Jointly learn SVM and kernel parameters.
- Kernel: $K = \sum_i d_i K_i$ with $\|\mathbf{d}\|_{p=1} = 1$.
- The MKL dual has quadratic constraints



$$\begin{aligned} \max \quad & \mathbf{1}^t \boldsymbol{\alpha} - \mu \\ \text{s. t.} \quad & \mathbf{0} \leq \boldsymbol{\alpha} \leq \mathbf{C}, \mathbf{1}^t \mathbf{Y} \boldsymbol{\alpha} = 0 \\ & \frac{1}{2} \boldsymbol{\alpha}^t \mathbf{Y} \mathbf{K}_i \mathbf{Y} \boldsymbol{\alpha} \leq \mu \end{aligned}$$

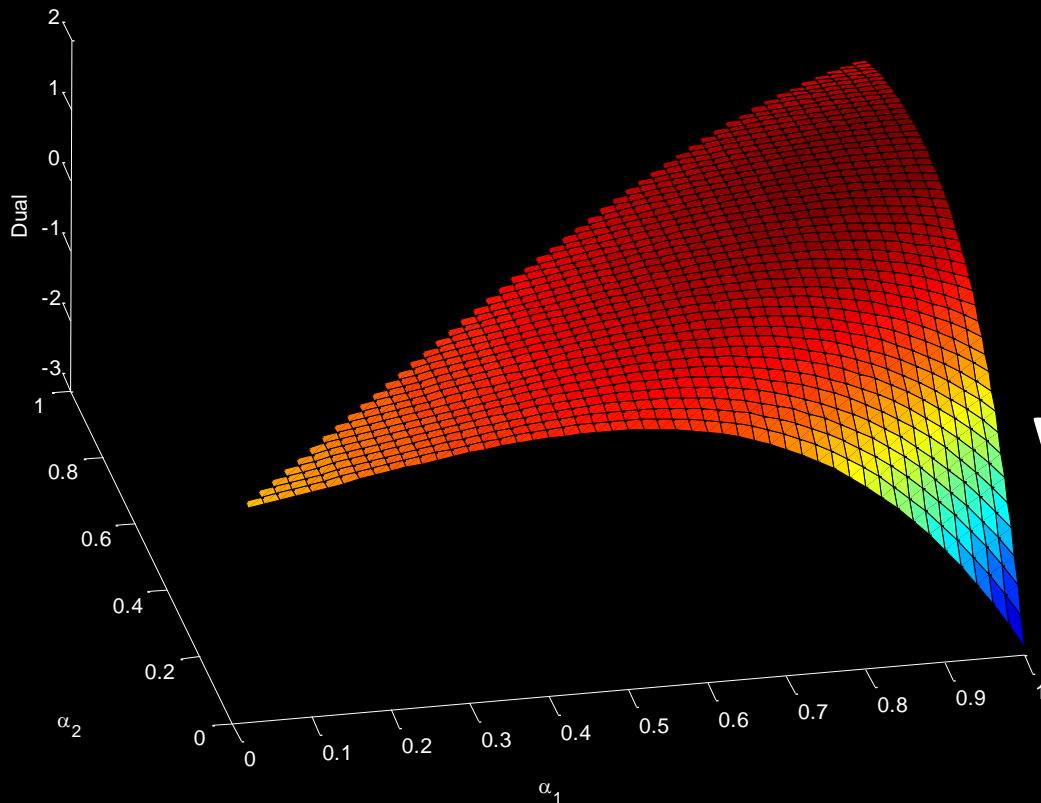
Eliminating the constraints leads to a non-smooth dual



$$\begin{aligned} \max \quad & \mathbf{1}^t \boldsymbol{\alpha} - \max_i \frac{1}{2} \boldsymbol{\alpha}^t \mathbf{Y} \mathbf{K}_i \mathbf{Y} \boldsymbol{\alpha} \\ \text{s. t.} \quad & \mathbf{0} \leq \boldsymbol{\alpha} \leq \mathbf{C}, \mathbf{1}^t \mathbf{Y} \boldsymbol{\alpha} = 0 \end{aligned}$$

Our Approach – SMO-MKL

- Kernel: $K = \sum_i d_i K_i$ with minimum $\|\mathbf{d}\|_{p>1}^2$
- The SMO-MKL dual



$$\max \quad \mathbf{1}^t \alpha - \frac{1}{8} |\mathbf{g}|_q^2$$

$$\text{s. t.} \quad \mathbf{0} \leq \alpha \leq \mathbf{C}$$

$$\mathbf{1}^t \mathbf{Y} \alpha = 0$$

where $g_i = \frac{1}{2} \alpha^t \mathbf{Y} K_i \mathbf{Y} \alpha$

$$\frac{1}{p} + \frac{1}{q} = 1$$

Code: <http://research.microsoft.com/~manik/code/SMO-MKL/download.html>

SMO-MKL Training Times

- Web with 50K data points and 50 kernels: < 30 minutes
- Sonar with a hundred thousand kernels
 - Pre-computed kernels: < 7 minutes
 - Kernels computed on-the-fly: < 30 minutes
- Sonar with nearly 800 kernels

p	Training Time (s)		# of Kernels Selected	
	SMO-MKL	Shogun	SMO-MKL	Shogun
1.1	4.95	47.19	91.2	258.0
2.0	3.31	31.52	661.2	664.8
3.0	3.96	70.08	786.0	792.2

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