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Question 1:

Given: $\min_{w,\xi,\rho} \frac{1}{2} w^T S w - \upsilon\rho + \Sigma_t C^t \xi^t,$

subject to $\begin{cases} r^t(w^T x^t + w_0) \geq \rho - \xi^t \\ \xi^t \leq 0 \\ \rho \geq 0 \end{cases}$

S is positive definite

$C^t > 0 \; \forall t$

$$L_\rho = \frac{1}{2} w^T S w - \upsilon\rho + \Sigma_t C^t \xi^t - \Sigma_t \alpha^t [r^t(w^T x^t + w_0) - \rho + \xi^t] - \Sigma_t \mu^t \xi^t - n\rho$$

$$\frac{\partial L_\rho}{\partial w} = Sw - \Sigma_t \alpha^t r^t x^t$$

$$\frac{\partial L_\rho}{\partial w_0} = -\Sigma_t \alpha^t r^t$$

$$\frac{\partial L_\rho}{\partial \rho} = -\upsilon + \Sigma_t \alpha^t - n$$

$$\frac{\partial L_\rho}{\partial \xi^t} = -\mu^t + C^t - \alpha^t$$

$$L_\rho = \frac{1}{2} w^T \Sigma_t \alpha^t r^t x^t - \Sigma_t \alpha^t [r^t(w^T x^t)]$$
$$= \frac{1}{2} w^T \Sigma_t \alpha^t r^t x^t - \Sigma_t \alpha^t r^t w^T x^t$$
$$= -\frac{1}{2} \Sigma_t w^T \alpha^t r^t x^t$$
$$= -\frac{1}{2} \Sigma_t w^T s^T s^{-1} \alpha^t r^t x^t$$
$$= -\frac{1}{2} \Sigma_t \alpha^t r^t (\Sigma_k \alpha^k r^k x^k)^T s^{-1} x^t$$
$$= -\frac{1}{2} \Sigma_t \Sigma_k \alpha^t r^t \alpha^k r^k (x^k)^T s^{-1} x^t$$

$$\boxed{\begin{array}{l} = -\frac{1}{2} \Sigma_t \Sigma_k \alpha^t \alpha^k r^t r^k (x^k)^T s^{-1} x^t \\ \text{subject to } \Sigma_t \alpha^t r^t = 0, 0 \leq \alpha^t \leq C^t, \Sigma_t \alpha^t > \upsilon, \forall t \end{array}}$$

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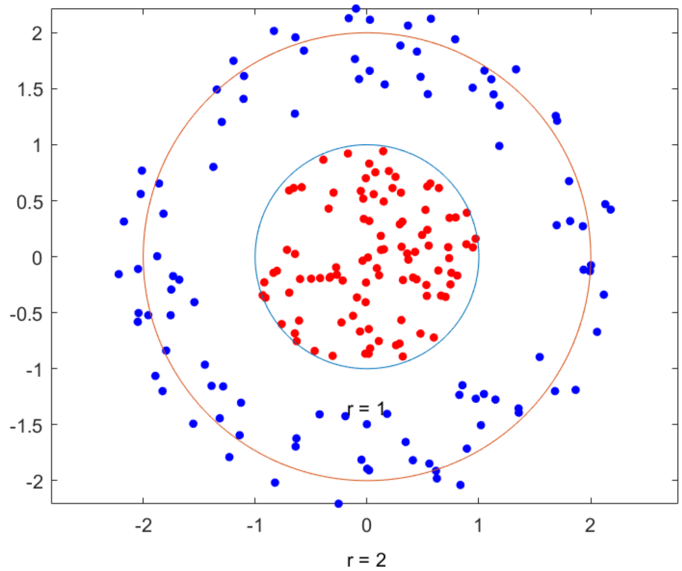
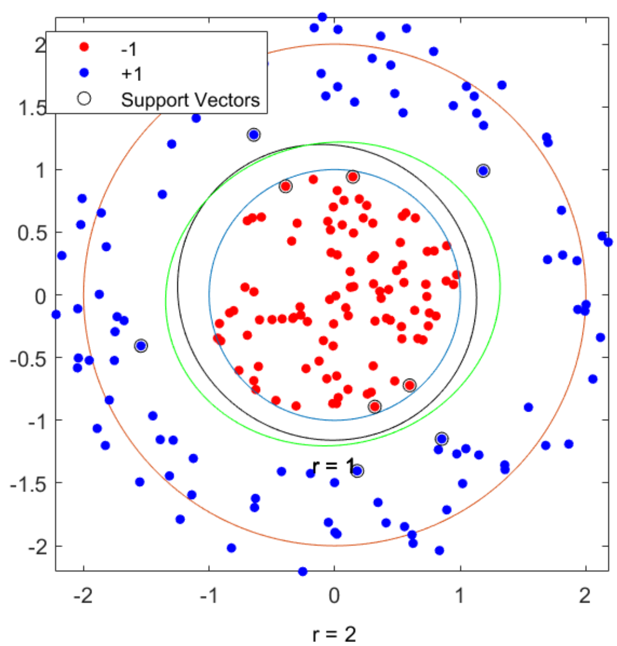
Question 2a:

Kernel Perceptron
Error Rate: 0



Question 2b:

Kernel Perceptron & SVM
BoxConstraint: 1



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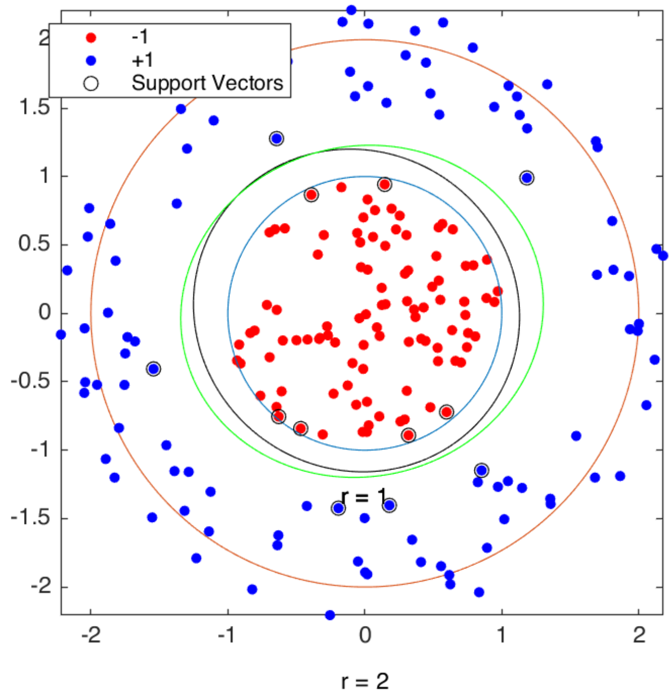
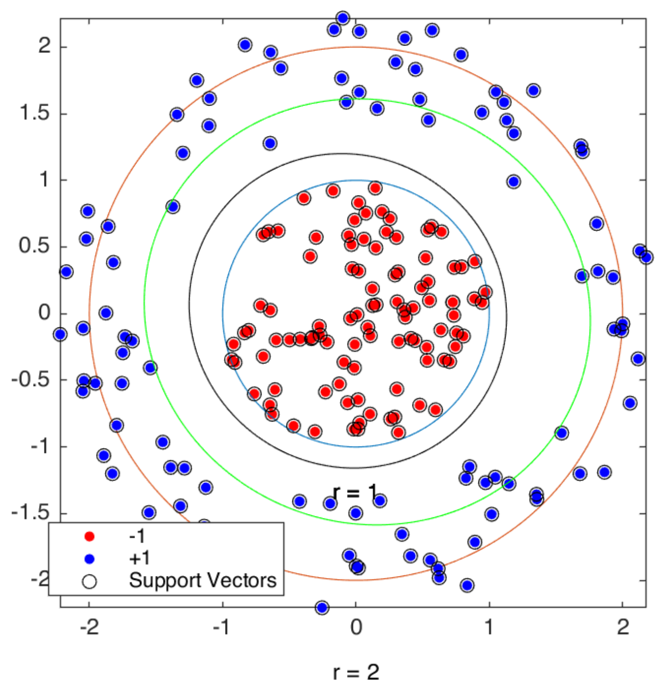
BoxConstraint: 0.5



BoxConstraint: 0.001



Increasing the BoxConstraint value is correlated with an increased cost of any misclassified points. This results in a more severe separation of the data.

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Question 2c:

optdigits49 Training Error Rate: 0.01182
optdigits49 Testing Error Rate: 0.024648

optdigits79 Training Error Rate: 0.013002
optdigits79 Testing Error Rate: 0.014184