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Machine Learning with Python-From Linear Models to Deep Learning

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4. Motivation for Kernels: Computational Efficiency

Motivation for Kernels: Computational Efficiency



Kernels vs features

- For **some** feature maps, we can evaluate the inner products very efficiently, e.g.,

$$K(x, x') = \phi(x) \cdot \phi(x') = (1 + x \cdot x')^P$$

$P = 1, 2, \dots$



- In those cases, it is advantageous to express the linear classifiers (regression methods) in terms of kernels rather than explicitly constructing feature vectors

$$\text{sign}(\theta \cdot \phi(x) + \theta_0) \rightarrow K(x, x')$$

takes $\theta \cdot \phi(x)$ plus θ_0 and tries to classify that-- that's how a linear classifier.

Somehow, we wish to turn that inter-classifier that only depends on those inner products operates in terms of kernels.

And we'll do that in the context of kernel perception

just for simplicity.

But it applies to any linear method

that you've already learned.



5:34 / 5:34

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Kernels as Dot Products 1

1/1 point (graded)

Let us go through the computation in the video above. Assume we map x and $x' \in \mathbb{R}^2$ to feature vectors $\phi(x)$ and $\phi(x')$ given by

$$\begin{aligned}\phi(x) &= [x_1, x_2, x_1^2, \sqrt{2}x_1x_2, x_2^2] \\ \phi(x') &= [x'_1, x'_2, x'^2_1, \sqrt{2}x'_1x'_2, x'^2_2].\end{aligned}$$

Which of the following equals the dot product $\phi(x) \cdot \phi(x')$?

☐ $x \cdot x'$
☒ $x \cdot x' + (x \cdot x')^2$ ✓

☐ $(x \cdot x')^2$
☐ $2(x \cdot x')^2$
☐ None of the above

Solution:

Expand $\phi(x) \cdot \phi(x')$ to get

$$\begin{aligned}\phi(x) \cdot \phi(x') &= x_1x'_1 + x_2x'_2 + x_1x'^2_1 + 2x_1x'_1x_2x'_2 + x_2x'^2_2 \\ &= (x_1x'_1 + x_2x'_2) + (x_1x'_1 + x_2x'_2)^2 \\ &= x \cdot x' + (x \cdot x')^2.\end{aligned}$$

Remark: Notice the coefficient $\sqrt{2}$ of the x_1x_2 terms is necessary for rewriting $\phi(x) \cdot \phi(x')$ as the function above of $x \cdot x'$.

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Kernels as Dot Products 2

1/1 point (graded)

Which of the following feature vectors $\phi(x)$ produces the kernel

$$K(x, x') = \phi(x) \cdot \phi(x') = x_1 x'_1 + x_2 x'_2 + x_3 x'_3 + x_2 x'_3 + x_3 x'_2$$

(Choose all that apply.)

☐ $\phi(x) = [x_1, x_2, x_3]$

☐ $\phi(x) = [x_1 + x_2 + x_3]$

☒ $\phi(x) = [x_1, x_2 + x_3]$ ✓

☐ $\phi(x) = [x_1 + x_3, x_1 + x_2]$

Solution:

Directly expand to see the answer. The fact that there are mixed terms in the kernel, e.g. $x_2 x'_3$, indicates that some coordinates of the feature vector must be mixed, i.e. contain different x_i 's.

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You have used 1 of 1 attempt

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<div><div>?</div><div>Computational cost of additional features</div><div>Is not just in creating them by inner product, but also in calculating parameter updates, when there are so many features correct ? In addition, how a dot product of (x1, x2, x3),...</div></div>	2

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