6. Kernel Composition Rules

Exercises due Oct 14, 2020 05:29 IST *Completed*

Kernel Composition Rules

Start of transcript. Skip to the end.

Now instead of directly constructing feature vectors

by adding coordinates and then taking it in the product

and seeing how it collapses into a kernel,

we can construct kernels directly from simpler kernels.

So here are simple composition rules for kernels.

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Video

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Kernel Composition Rules 1

1/1 point (graded)

Recall from the video above that if $f:\mathbb{R}^d \to \mathbb{R}$ and $K(x,x')$ is a kernel, so is

$$\widetilde{K}(x,x') = f(x)\,K(x,x')\,f(x').$$

If there exists $\phi(x)$ such that

$$K(x,x') = \phi(x)\cdot\phi(x'),$$

then which of the following φ gives

$$\widetilde{K}(x,x') = \varphi(x)\cdot\varphi(x')?$$

- ○ $\varphi(x) = f(x)\,K(x,x)$
- ○ $\varphi(x) = f(x)\,K(x,x')$
- ○ $\varphi(x) = f(x)$
- ● $\varphi(x) = f(x)\,\phi(x)$

✔

Solution:

As $f(x), f(x') \in \mathbb{R}$, we have $(f(x)\phi(x)) \cdot (f(x')\phi(x')) = \widetilde{K}(x, x')$. Hence $\varphi(x) = f(x)\phi(x)$ gives $\widetilde{K}(x, x') = \varphi(x) \cdot \varphi(x')$.

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Answers are displayed within the problem

Kernel Composition Rules 2

1/1 point (graded)
Let x and x' be two vectors of the same dimension. Use the the definition of kernels and the kernel composition rules from the video above to decide which of the following are kernels. (Note that you can use feature vectors $\phi(x)$ that are not polynomial.)
(Choose all those apply.)

- [x] 1
- [x] $x \cdot x'$
- [x] $1 + x \cdot x'$
- [x] $(1 + x \cdot x')^2$
- [x] $\exp(x + x')$, for x,x' $\in \mathbb{R}$
- [ ] $\min(x, x')$, for x,x' $\in \mathbb{Z}$

✔

Solution:

We go through the choices in order:

- Yes, for $\phi(x) = 1$.
- Yes, for $\phi(x) = x$.
- Yes, since the sum of kernels are kernels. In this case, we can also easily see $\phi(x) = [1, x]^T$ works.
- Yes, since the product of kernels are kernels. (In this case, factoring the kernel as dot products are more involved, and the composition rule saves this work.)
- Yes, for $\phi(x) = \exp(x)$.
- No. For example, $\min(-1, -1) = -1 < 0$ and hence cannot be written as a dot product and is not a valid kernel.

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Answers are displayed within the problem

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  What is the corresponding phi(x) for composition rule 4?
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  If f(x) is a real number, why would it matter whether you multiply on the left or right?
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  Can't we have a kernel of a function that evaluates to a negative number? Why not?? Thanks
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  How do we prove the fourth composition rule??
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