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9. Cubic Features

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## 9. Cubic Features

In this section, we will work with a **cubic feature** mapping which maps an input vector  $x = [x_1, \dots, x_d]$  into a new feature vector  $\phi(x)$ , defined so that for any  $x, x' \in \mathbb{R}^d$ :

$$\phi(x)^T \phi(x') = (x^T x' + 1)^3$$

**You will be working in the files `part1/main.py` and `part1/features.py` in this problem**

## Computing Cubic Features

3.0/3.0 points (graded)

In 2-D, let  $x = [x_1, x_2]$ . Write down the explicit cubic feature mapping  $\phi(x)$  as a vector; i.e.,  $\phi(x) = [f_1(x_1, x_2), \dots, f_N(x_1, x_2)]$

[STANDARD NOTATION](#)

**Hint****Hint:**  $\phi(x)$  should be a 10-dimensional vector.[Hide](#) $\phi(x) = [x_1^3, \sqrt{3}x_1^2x_2, \sqrt{3}x_1x_2^2, x_2^3, \sqrt{3}x_1^2, \sqrt{3}x_1x_2, \sqrt{3}x_2^2, x_1^2, x_2^2, 1]$  ✓**Answer:**  $[x_1^3, \sqrt{3}x_1^2x_2, \sqrt{3}x_1x_2^2, x_2^3, \sqrt{3}x_1^2, \sqrt{3}x_1x_2, \sqrt{3}x_2^2, x_1^2, x_2^2, 1]$ [Submit](#)

You have used 3 of 20 attempts

**i** Answers are displayed within the problem

The `cubic_features` function in `features.py` is already implemented for you. That function can handle input with an arbitrary dimension and compute the corresponding features for the cubic Kernel. Note that here we don't leverage the kernel properties that allow us to do a more efficient computation with the kernel function (without computing the features themselves). Instead, here we do compute the cubic features explicitly and apply the PCA on the output features.

## Applying to MNIST

1.0/1.0 point (graded)

If we explicitly apply the cubic feature mapping to the original 784-dimensional raw pixel features, the resulting representation would be of massive dimensionality. Instead, we will apply the quadratic feature mapping to the 10-dimensional PCA representation of our training data which we will have to calculate just as we calculated the 18-dimensional representation in the previous problem. After applying the cubic feature mapping to the PCA representations for both the train and test datasets, retrain the softmax regression model using these new features and report the resulting test set error below.

**Important:** You will probably get a runtime warning for getting the log of 0, ignore. Your code should still run and perform correctly.

**Note:** Use the same training parameters as the first softmax model given in `main.py` file and temperature 1.

If you have done everything correctly, softmax regression should perform better (on the test set) using these features than either the 18-dimensional principal components or raw pixels. The error on the test set using cubic features should only be around 0.08, demonstrating the power of nonlinear classification models.

Error rate for 10-dimensional cubic PCA features = 0.08399999999999996

✓ **Answer:** 0.0849

Submit

You have used 1 of 20 attempts

**i** Answers are displayed within the problem

## Discussion

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? [Staff] Is the guidance of "error around 0.08" correct

[Edits by staff:] the problem described in the post is caused by the error in `project\_onto\_PC(... 3 new\_

**Pinned**

🗨 All deadlines postponed of 1 Week

Just to be sure all students get the info that has been sent my email today, I forward its conte... 23

**Pinned** **Community TA**

🗨 [staff] Invalid Input: 1 parenthesis was opened without being closed

hello, I have a notation problem in the exercize "Computing Cubic Features". The follwing me... 2

💬	<a href="#">Cost function vs the iteration nr graph oscillating</a>	3
	<a href="#">When softmax was trained with all features or with pca=18 I saw a much stable curve than w...</a>	
✓	<a href="#">Computing Cubic Features - Standard Notation Question [Solved]</a>	3
	<a href="#">Hi to all, while I think, I have the answer, I seem to be having issues writing it correctly using t...</a>	
?	<a href="#">PCA Error Rate</a>	2
	<a href="#">I am getting.[edited] with temp=0.9999 and with temp=1, error as 0.0819...still the system is ...</a>	
💬	<a href="#">Hint: mimic Unit 2 Nonlinear Classification, Linear regression, Collaborative Filtering.(2 weeks) Homework 3 3. Kernels</a>	2
	<a href="#">Finally, I managed to get 3/3 for the 9. Cubic Features! Hint: mimic the steps in Unit 2 Nonline...</a>	
💬	<a href="#">[staff] Computing cubic taking a long time</a>	4
	<a href="#">I am not sure but my cubic function is taking a very long time on the data. Any one has this pr...</a>	
💬	<a href="#">How do I know when to use cubic features or other dimension feature mapping..</a>	2
	<a href="#">I got the answer of the exercise and I was impressed by how much the test error got to impr...</a>	
✓	<a href="#">are center_date and reconstruct_PC problematic?</a>	2
	<a href="#">There is running error on the reconstruct_PC, when tracing the code, I found that it uses cent...</a>	
?	<a href="#">Naive question for Cubic Features: Why is there a 1?</a>	2

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