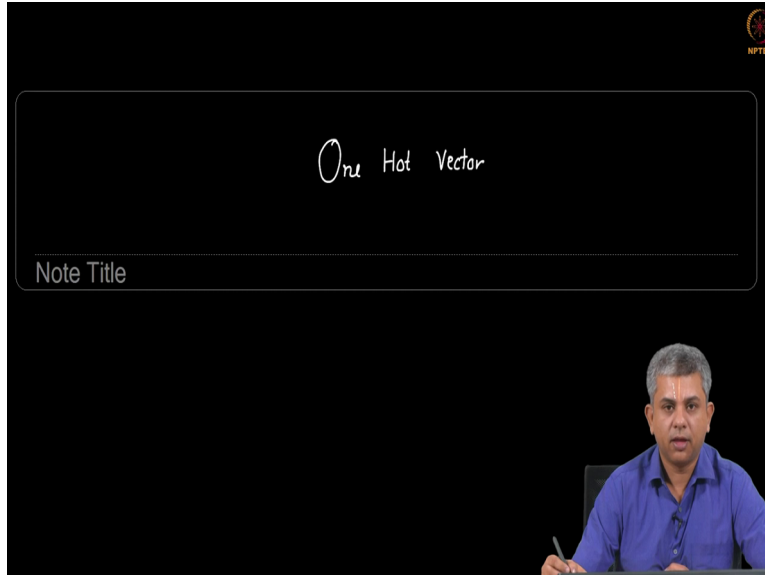


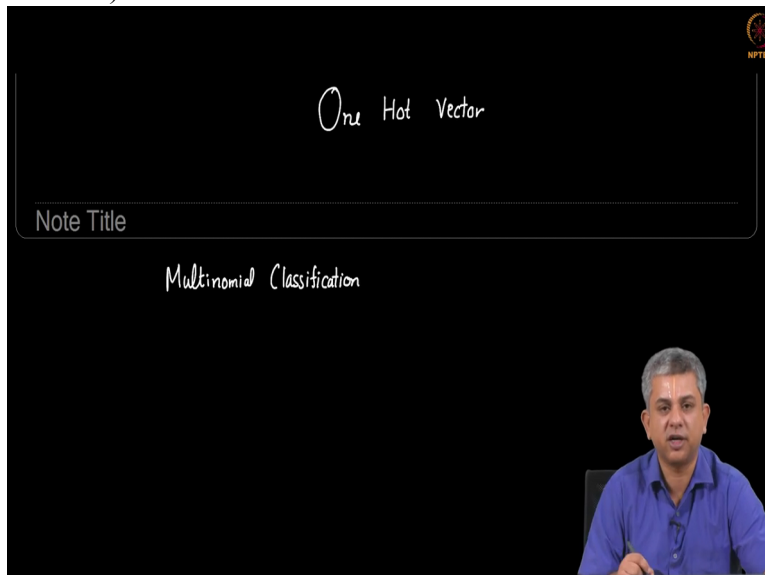
**Machine Learning for Engineering and Science Applications**  
**Professor Doctor Balaji Srinivasan**  
**Department of Mechanical Engineering**  
**Indian Institute of Technology Madras**  
**Multinomial Classification One Hot Vector**

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In this video we will be looking at the One Hot Vector representation. Remember that the One Hot Vector representation is used for a case where you have more than 2 classes. You can also use it for the case when you have just 2 classes but

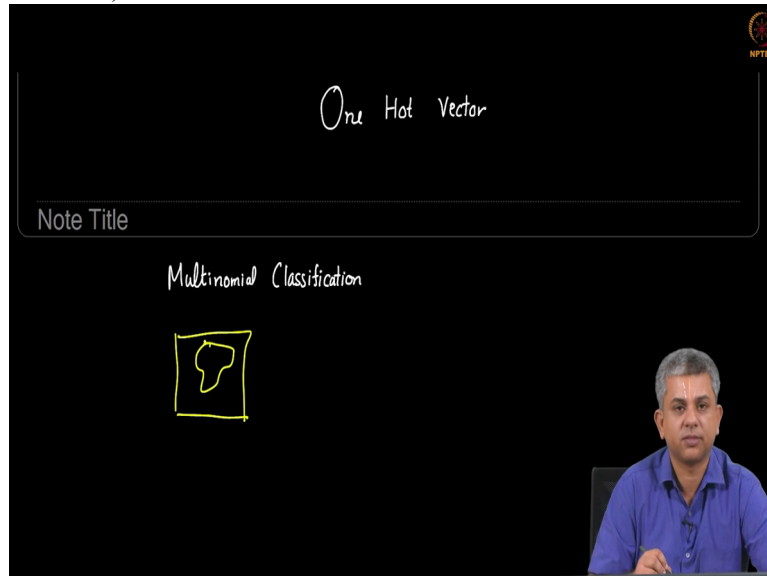
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it is generally overkill to use a One Hot Vector.

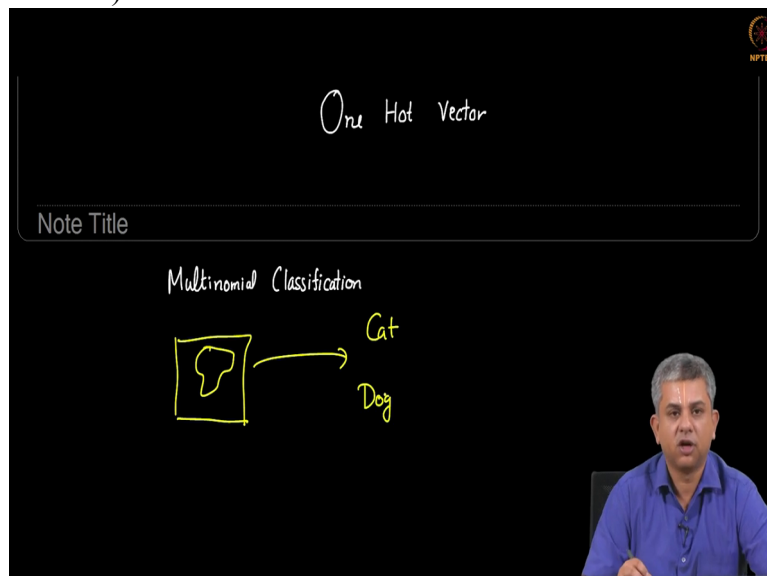
Let us start with a binary classification task and then we will go to a multinomial classification task and see how a One Hot Vector works. So let us say you have 2 classes. You have an image. And this image is that of a cat or a dog.

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And I want to represent the output. The output says either cat or it says dog.

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So earlier we would simply call cat as class 1

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One Hot Vector

Note Title

Multinomial Classification

Cat - 1  
Dog - 0

The slide features a black background with white and yellow text. At the top, the title 'One Hot Vector' is written in white. Below it is a white box labeled 'Note Title'. The main content is 'Multinomial Classification' in white, followed by a yellow square containing a white cat silhouette. An arrow points from the cat to the text 'Cat - 1' and 'Dog - 0' written in yellow. A small NPTEL logo is in the top right corner, and a video feed of a man in a blue shirt is in the bottom right.

and dog as class 0 or vice versa. Either way it is a simple number. Now in order to generalize for the multiple class cases we are going to represent our output instead as a vector.

So the vector is going to have 2 elements, Ok. So in the ideal case instead of calling cat simply 1, I would call it 1 0,

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One Hot Vector

Note Title

Multinomial Classification

Cat - 1  
Dog - 0

Vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$

The slide is similar to the previous one but includes a vector representation. The title 'One Hot Vector' and 'Note Title' box are the same. The 'Multinomial Classification' section is identical. To the right of the classification, the text 'Vector' is written in white, followed by a yellow vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$ . The NPTEL logo and video feed are also present.

this would represent cat. And I could call dog as 0 1. This would represent

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One Hot Vector

Note Title

Multinomial Classification

Cat - 1  
Dog - 0

Vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Cat

NPTEL

a dog. Essentially first element represents the cat;

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One Hot Vector

Note Title

Multinomial Classification

Cat - 1  
Dog - 0

Vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Cat

$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$  - Cat  
- Dog

NPTEL


the second element represents the dog, Ok.

Now how does this help? Let us go one more step. Let us say we have 3 classes. Let us say we have cats, dogs and horses. Once again the One Hot Vector then looks like 0 0 1 for a horse,

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Note Title

Multinomial Classification



Cat - 1  
Dog - 0

Cats, Dog, Horses

Vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$   
Cat

Vector  $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$   
Dog

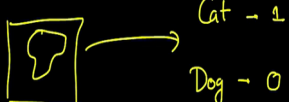
Vector  $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$   
Horse

0 1 0 for a dog. This is of course

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Note Title

Multinomial Classification



Cat - 1  
Dog - 0

Cats, Dog, Horses

Vector  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$   
Cat

Vector  $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$   
Dog

Vector  $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$   
Horse

arbitrary. You just have to make consistent choices, 1 0 0 for a cat.

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Note Title

Multinomial Classification

Cat - 1  
Dog - 0

Cats, Dog, Horses

Vector

Cat:  $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Dog:  $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$

Horse:  $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

Dog:  $\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$

Cat:  $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$

In general if our prediction is  $\hat{y}$ ,  $\hat{y}$  is going to have  $k$  elements,  $\hat{y}_1, \hat{y}_2$  so on and so forth up until

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Cats, Dog, Horses

Vector

Horse:  $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

Dog:  $\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$

Cat:  $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$

$\hat{y} = \begin{bmatrix} \hat{y}_1 \\ \hat{y}_2 \\ \vdots \\ \hat{y}_k \end{bmatrix}$

$\hat{y}_k$ . So  $k$  was 3 in our cats dogs horses example. What is the meaning of each of these terms? Let us think about this carefully.

So in my cats dogs horses example this is probability that my output belongs to class 1, Ok.

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Cats, Dog, Horses Vector -

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Horse

Prob that output belongs to class 1

Now my ideal output would be simply 1 0 0, 0 1 0 or 0 0 1, which is why it is called One Hot, that is only one element is 1,

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Cats, Dog, Horses Vector -

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Horse

Prob that output belongs to class 1

all the others are 0. That is why it is called One Hot Vector. All the others effectively are cold.

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However we know through logistic regression that we are not going to get precisely 0 or 1. We will get some number. This has to belong to some number

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between 0 and 1. What our actual prediction will typically look like something like this, point 9, point 0 1, point 0 9, something of that sort.

This would represent to us, if I have a number of this sort, that this has



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Handwritten slide content showing a vector representation for classes Cat, Dog, and Horse, and a probability vector  $\hat{y}$ .

Cats, Dog, Horse

Vector -

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Horse, Dog, Cat

Prob that output belongs to class 1  $\rightarrow \in [0, 1]$

$$\hat{y} = \begin{bmatrix} \hat{y}_1 \\ \hat{y}_2 \\ \vdots \\ \hat{y}_k \end{bmatrix}$$
$$\hat{y} = \begin{bmatrix} 0.9 \\ 0.01 \\ 0.03 \end{bmatrix}$$

a probability of point 9 then it is a cat, it has a probability of point 0 1 that it is a dog. And it is a probability of point 0 9 that it is a horse, Ok. So each element here, the element  $y$  hat  $k$  represents the probability, Ok.

I will first write it in words and then I will write it in more mathematical term, belongs to class  $k$ .

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Handwritten slide content showing a vector representation for classes Horse and One hot, and a probability vector  $\hat{y}$ .

Horse, One hot

Prob that output belongs to class 1  $\rightarrow \in [0, 1]$

$$\hat{y} = \begin{bmatrix} \hat{y}_1 \\ \hat{y}_2 \\ \vdots \\ \hat{y}_k \end{bmatrix}$$
$$\hat{y} = \begin{bmatrix} 0.9 \\ 0.01 \\ 0.03 \end{bmatrix}$$
$$\hat{y}_k = P(\text{belongs to class } k)$$

More precisely this is probability that  $y_k$  equal to 1 given whatever our input image, Ok.  $x$  here denotes the image in the example and in general it would denote whatever input we have here.

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that output belongs to class 1  
 $\rightarrow \in [0, 1]$

One hot

$$\hat{y} = \begin{bmatrix} \hat{y}_0 \\ \vdots \\ \hat{y}_k \end{bmatrix}$$
$$\hat{y} = \begin{bmatrix} 0.9 \\ 0.01 \\ 0.09 \end{bmatrix}$$
$$\hat{y}_k = P(\text{belongs to class } k)$$
$$\hat{y}_k = P(y_k = 1 | \tilde{x})$$

Image / Input

So this is the One Hot Vector and as you can see it can generalize to a, from a binary to a k class problem. We will be using this for multinomial classification.