

Linear Algebra for Computer Science

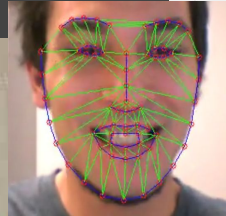
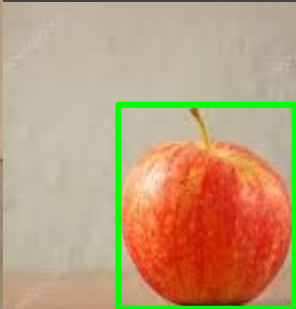
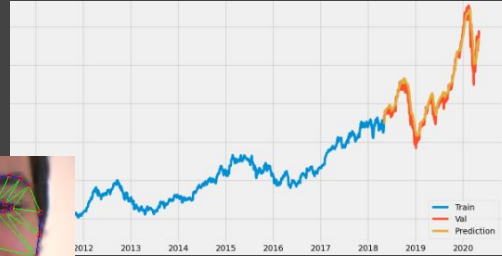
Lecture 2

Vectors

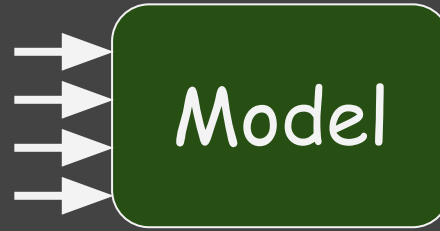
Machine Learning



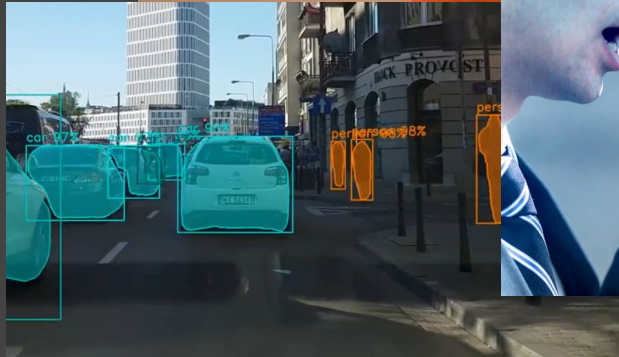
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input



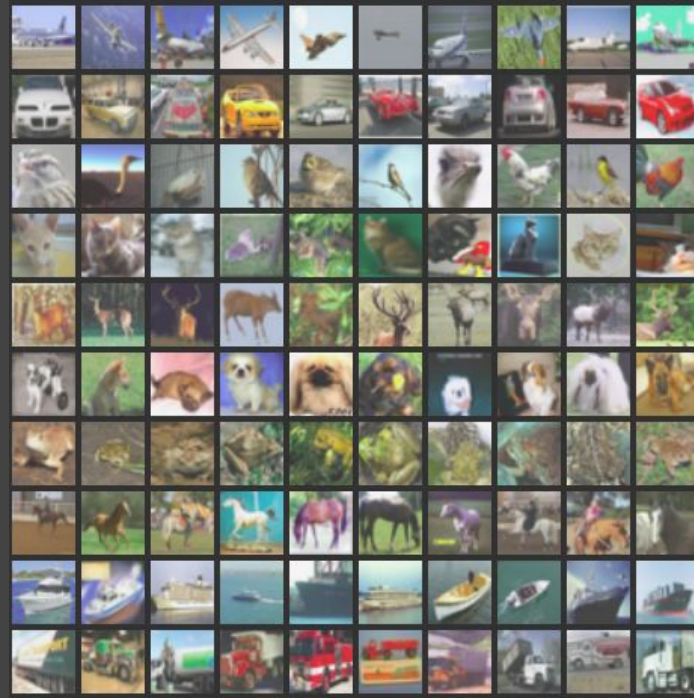
output



Learning from data



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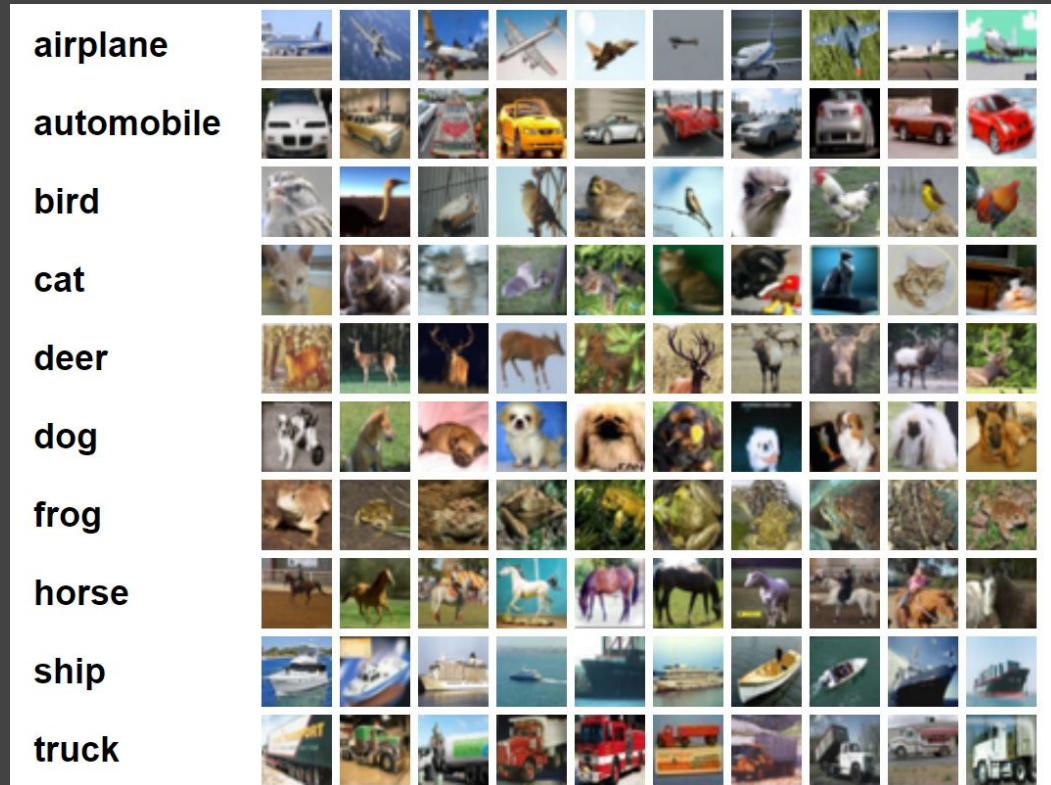


<https://www.analyticsvidhya.com/blog/2018/03/comprehensive-collection-deep-learning-datasets/>

Supervised Learning



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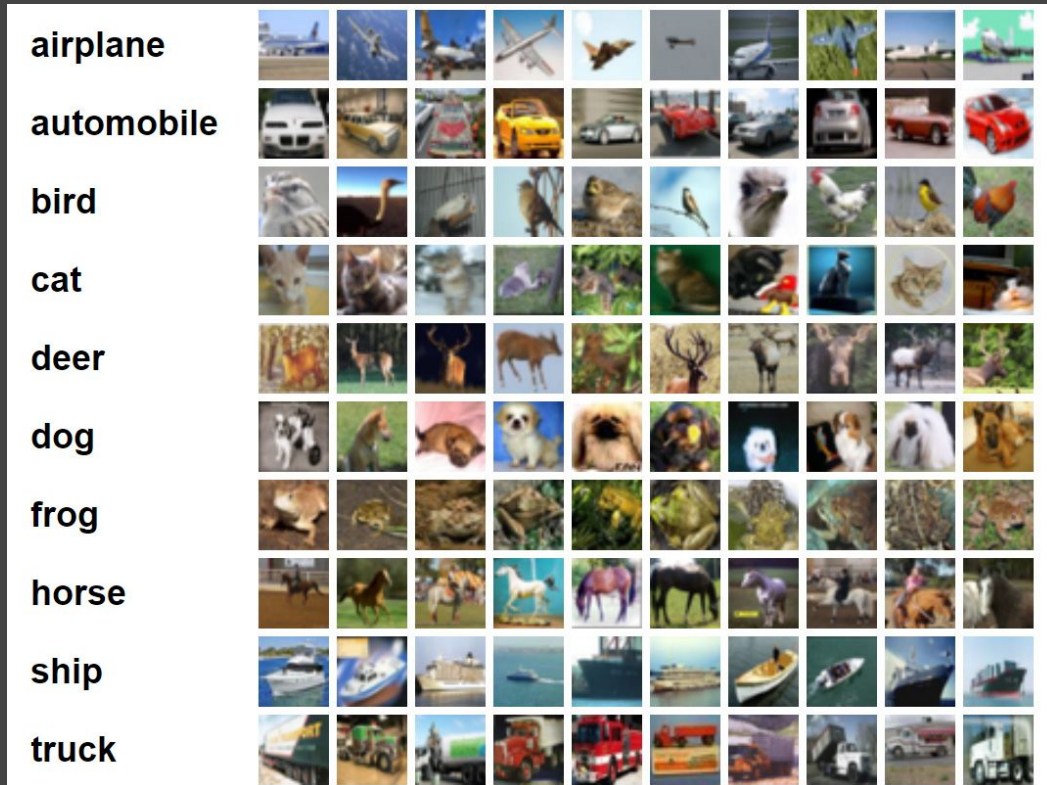


<http://seansoleyman.com/effect-of-dataset-size-on-image-classification-accuracy/>

Supervised Learning



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Training data:

X_1, y_1

X_2, y_2

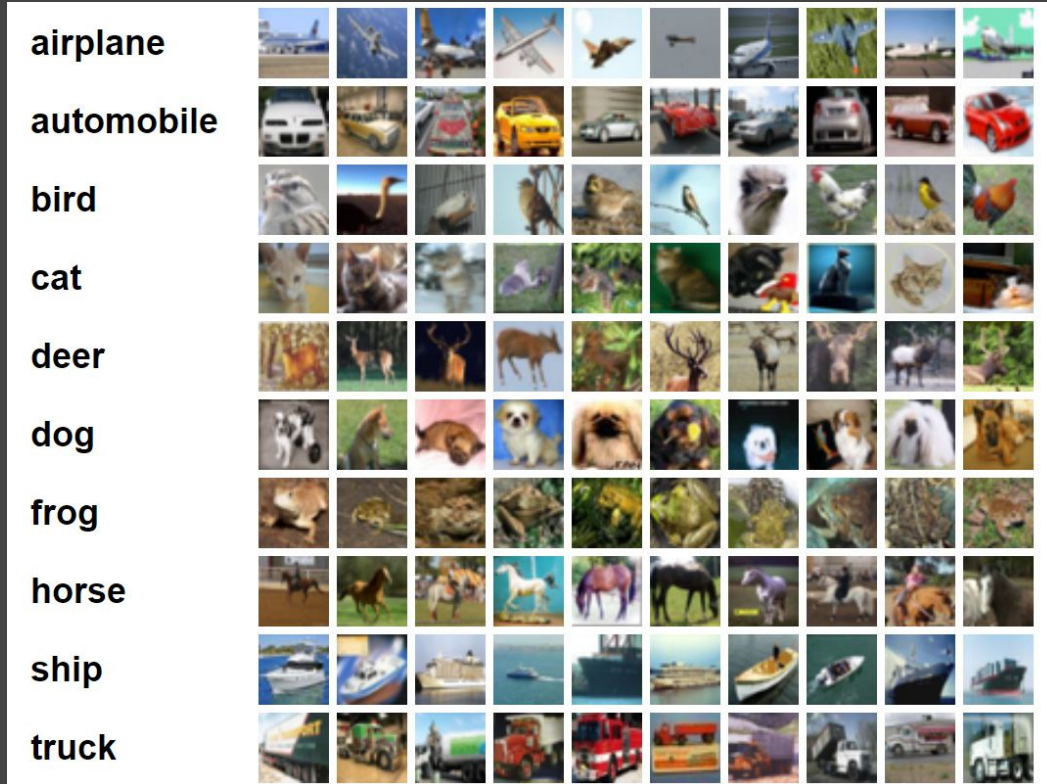
X_3, y_3

\vdots
 X_n, y_n

Supervised Learning



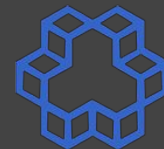
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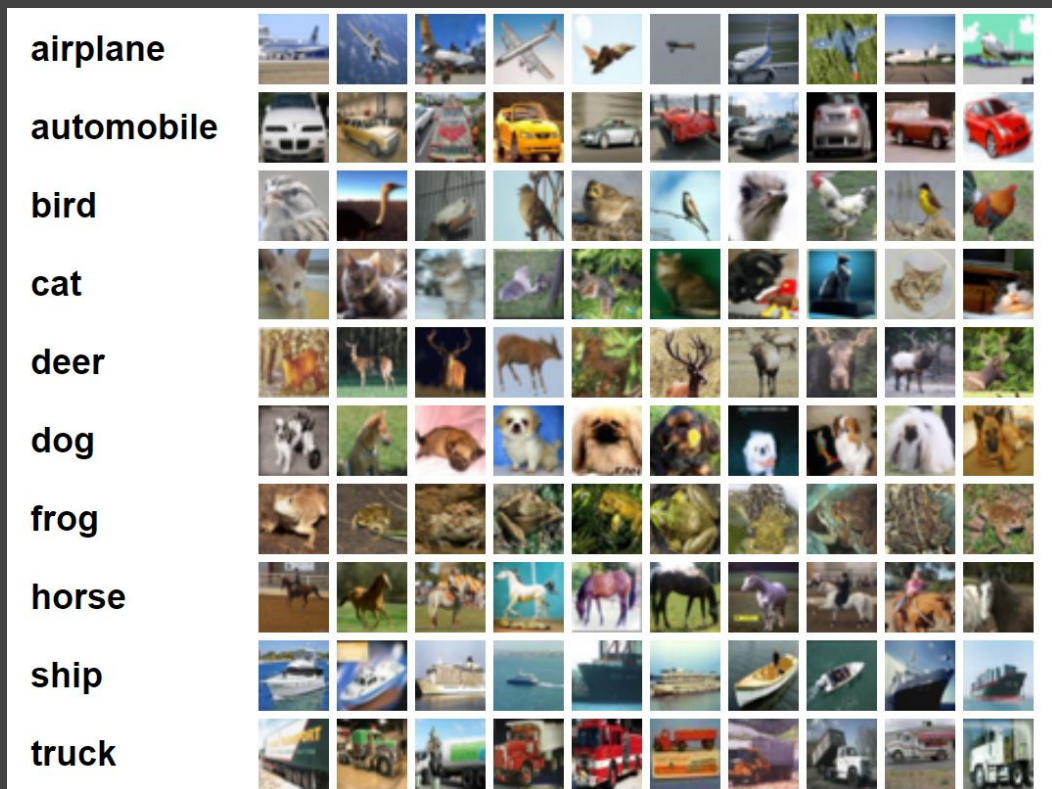
Training data:

	Apple
	Apple
	Orange
	Orange

Supervised Learning



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Training data:

	0
	0
	1
⋮	
	1

Supervised Learning



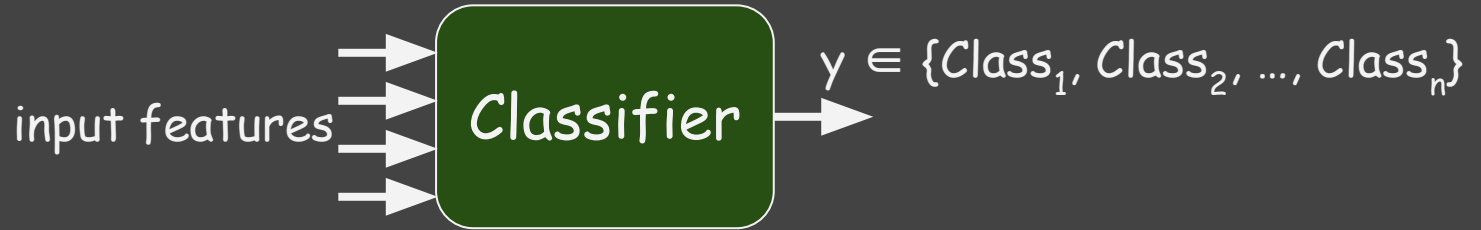
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Classification



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Classification



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Classification



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Regression



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Regression



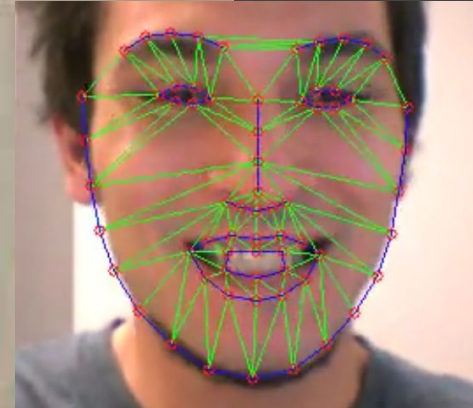
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Regression



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Learnable Models



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Learnable Models: Example



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Learnable Models: Example



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Learnable Models: Input-output map



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$$y = f(x)$$

$$f: \mathbb{R}^m \rightarrow \mathbb{R}^n$$

Learnable Models: Example

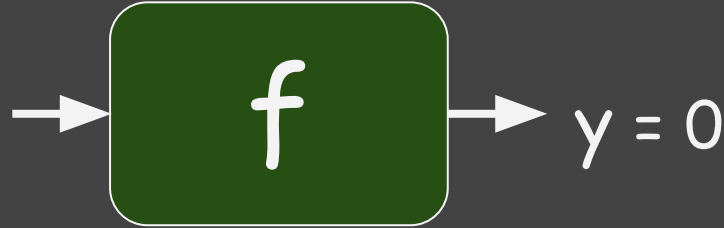


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I

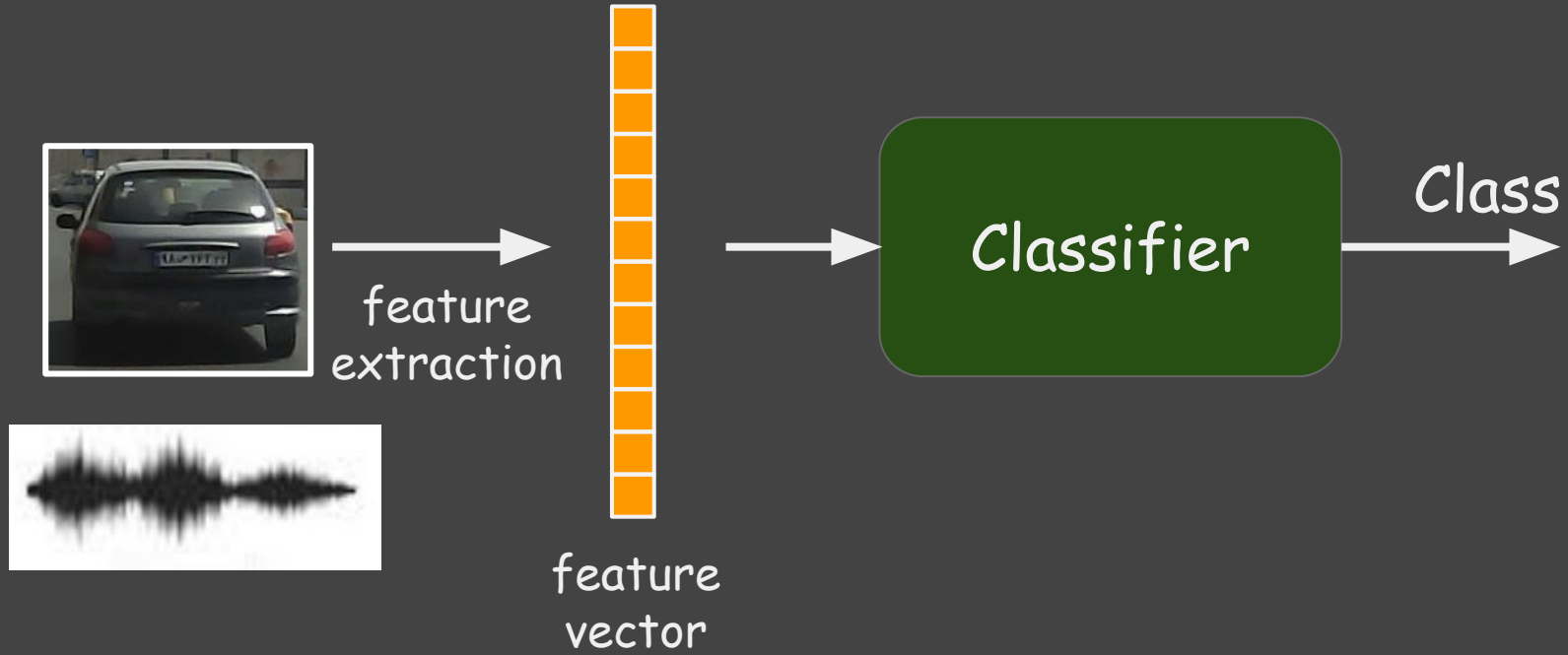
$x =$
 $\text{features}(I)$



$$y = f(x)$$

$$f: \mathbb{R}^m \rightarrow \mathbb{R}^n$$

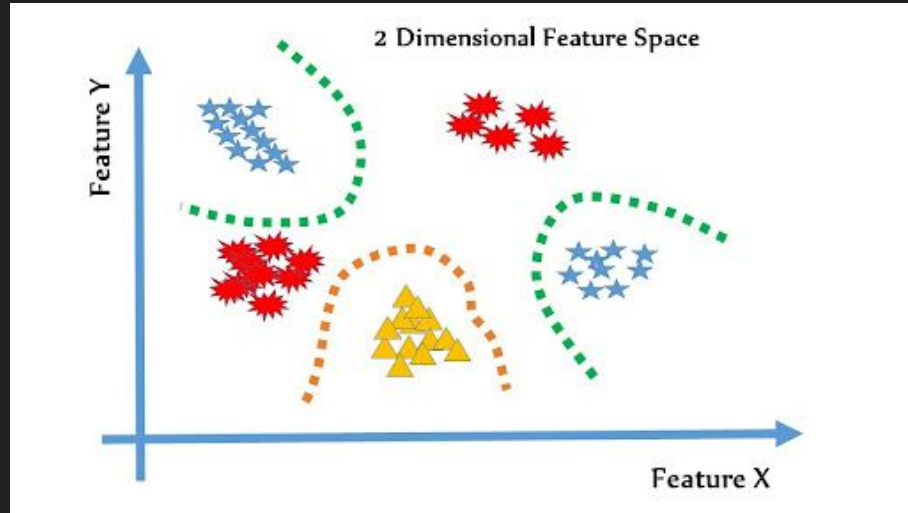
Features



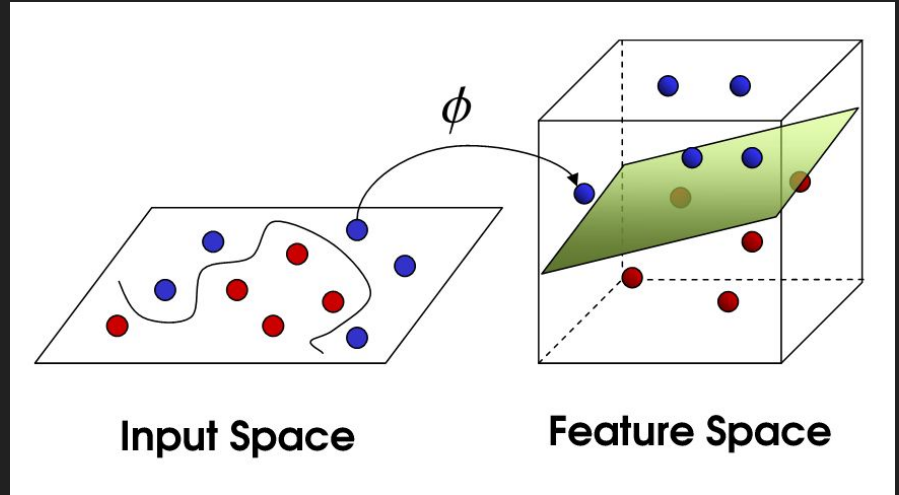
Feature space



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<https://www.petersincak.com/news/why-i-do-not-believe-in-error-backpropagation/>

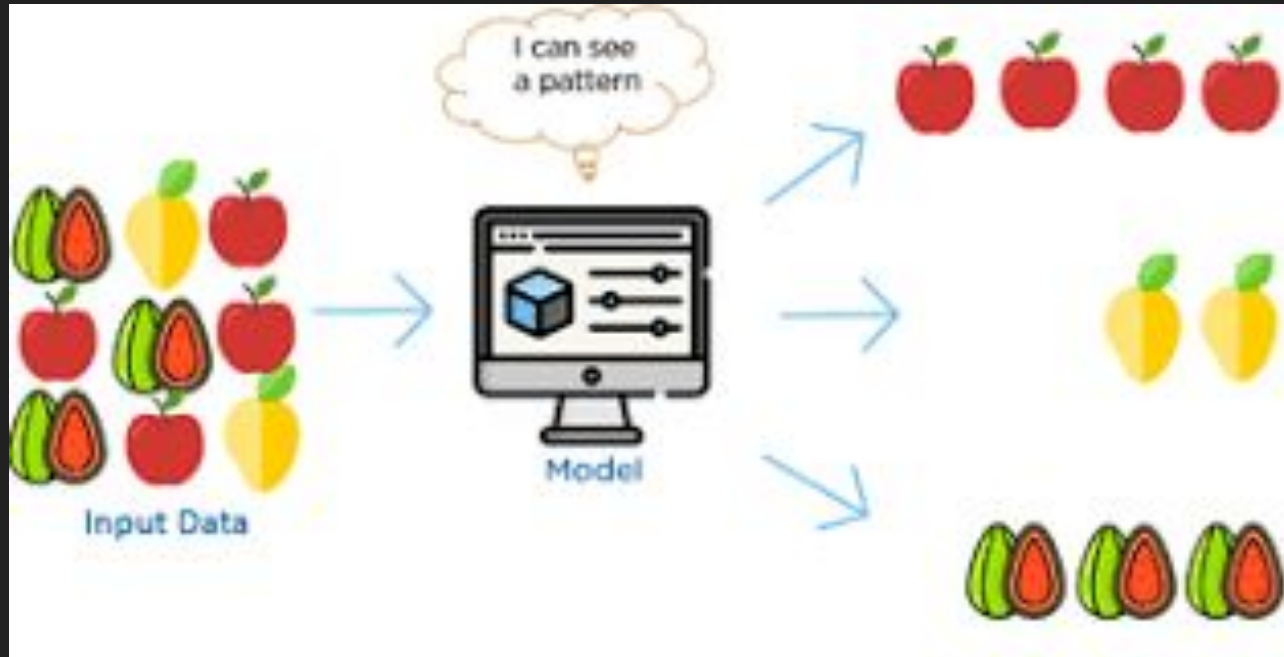


<https://towardsdatascience.com/the-kernel-trick-c98cdbcaeb3f>

Unsupervised Learning



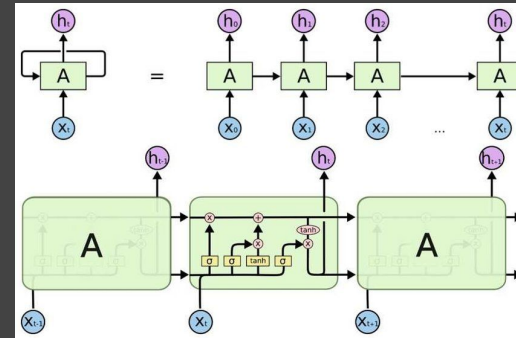
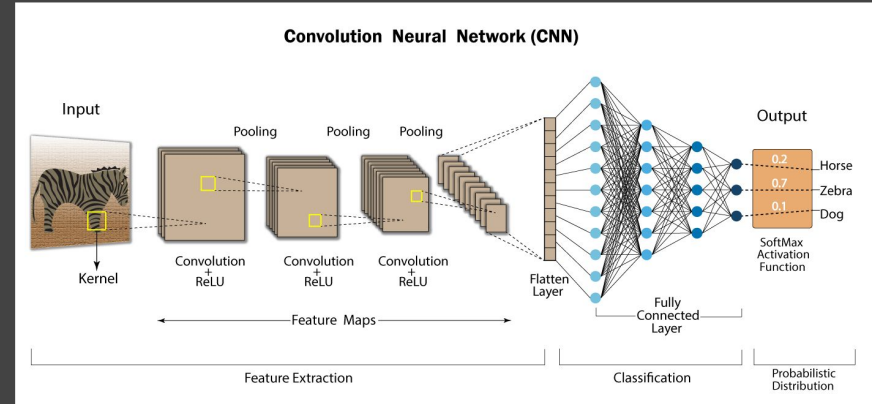
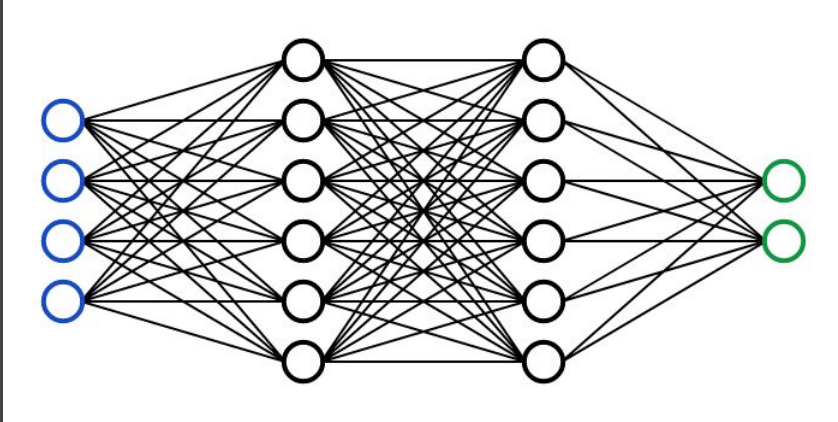
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Neural Networks



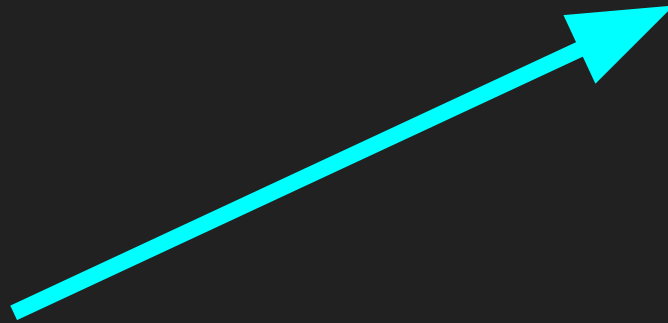
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What is a Vector?



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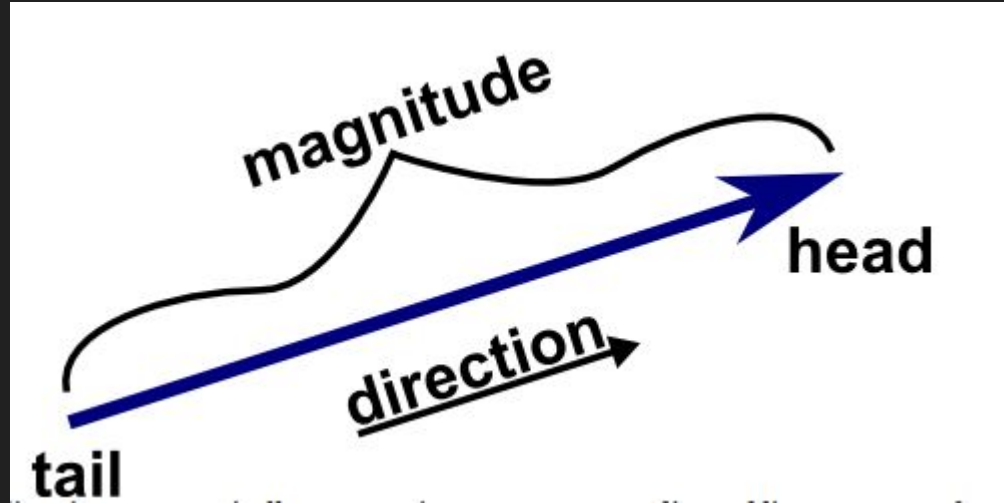


What is a Vector?



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$$\vec{B} = \begin{bmatrix} B_x \\ B_y \\ B_z \end{bmatrix}$$

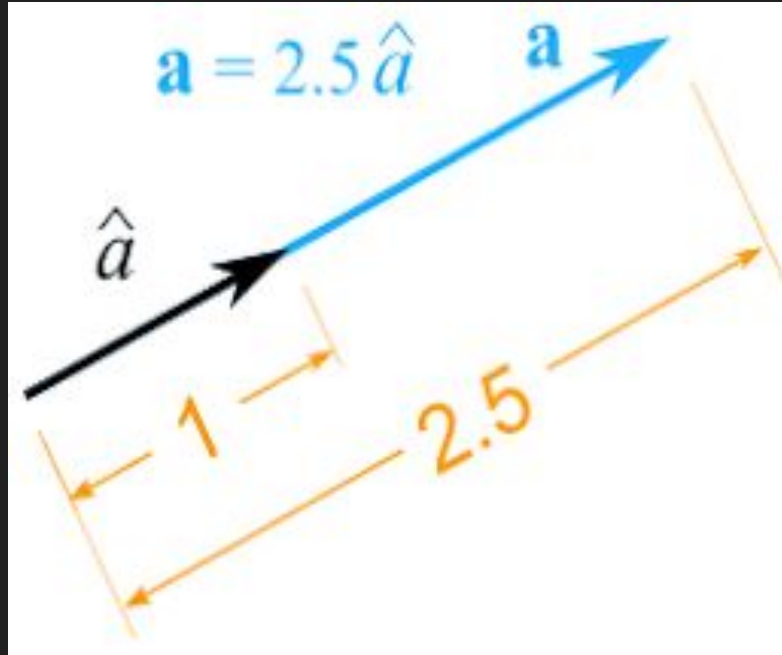


https://mathinsight.org/vector_introduction

Vector Scaling



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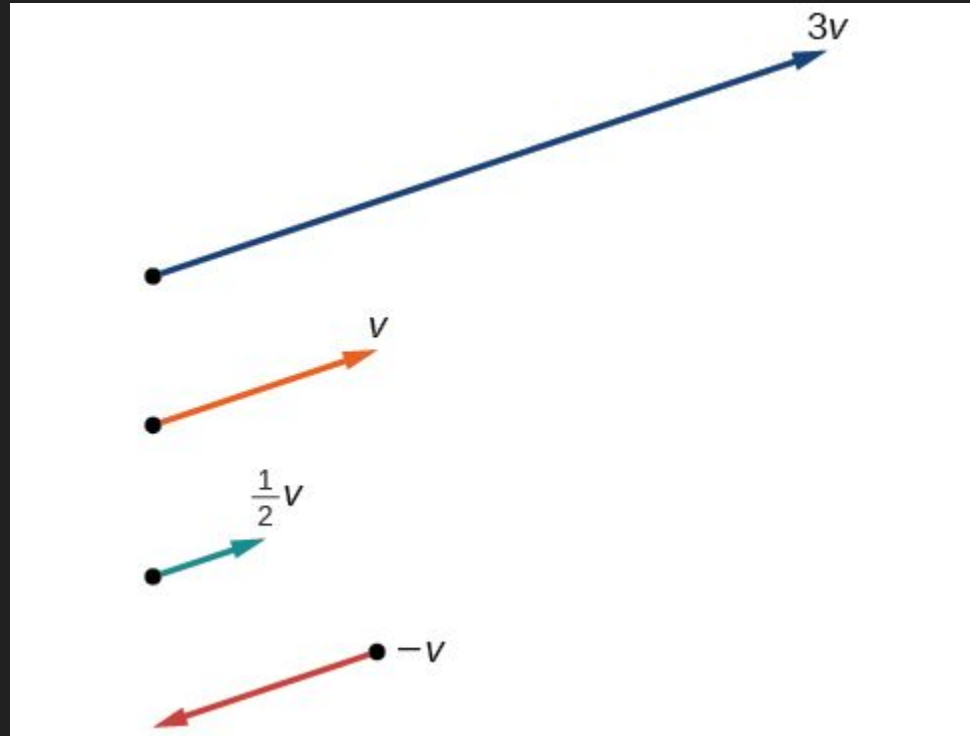


<https://semesters.in/unit-free-forced-fixed-vector/>

Vector Scaling



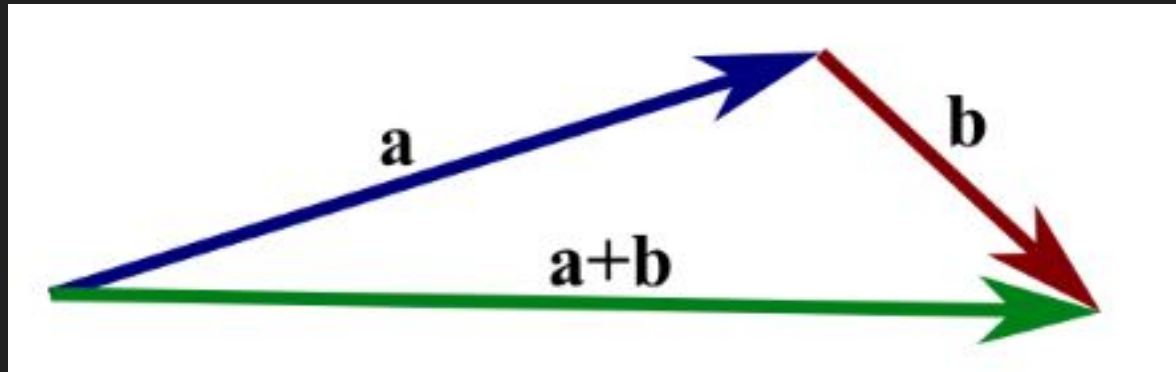
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Vector Addition



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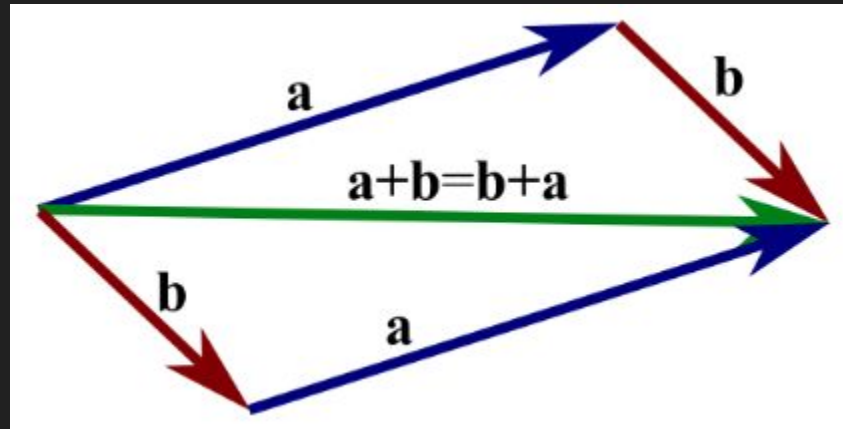


https://mathinsight.org/vector_introduction

Vector Addition



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https://mathinsight.org/vector_introduction

Space

A set with a structure



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Vector Spaces



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Vector Space



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- a set V
- scalars $\in \mathbb{R}$ (\mathbb{C} , or any field)
- Vector addition $+$ ($u + v$ for $u, v \in V$)
- scalar multiplication ($a u$ for $a \in \mathbb{R}, u \in V$)
 - Commutativity: $u + v = v + u$
 - Associativity: $u + (v + w) = (v + u) + w$
 - Identity element: $\exists z \in V : v + z = z + v = v$
 - Inverse: for each $v \in V$ there is v' : $v + v' = z$ (z defined above)
 - $(ab) v = a (b v)$
 - $1 v = v$
 - $a (u + v) = a u + a v$
 - $(a+b) v = a v + b v$

Why bother?

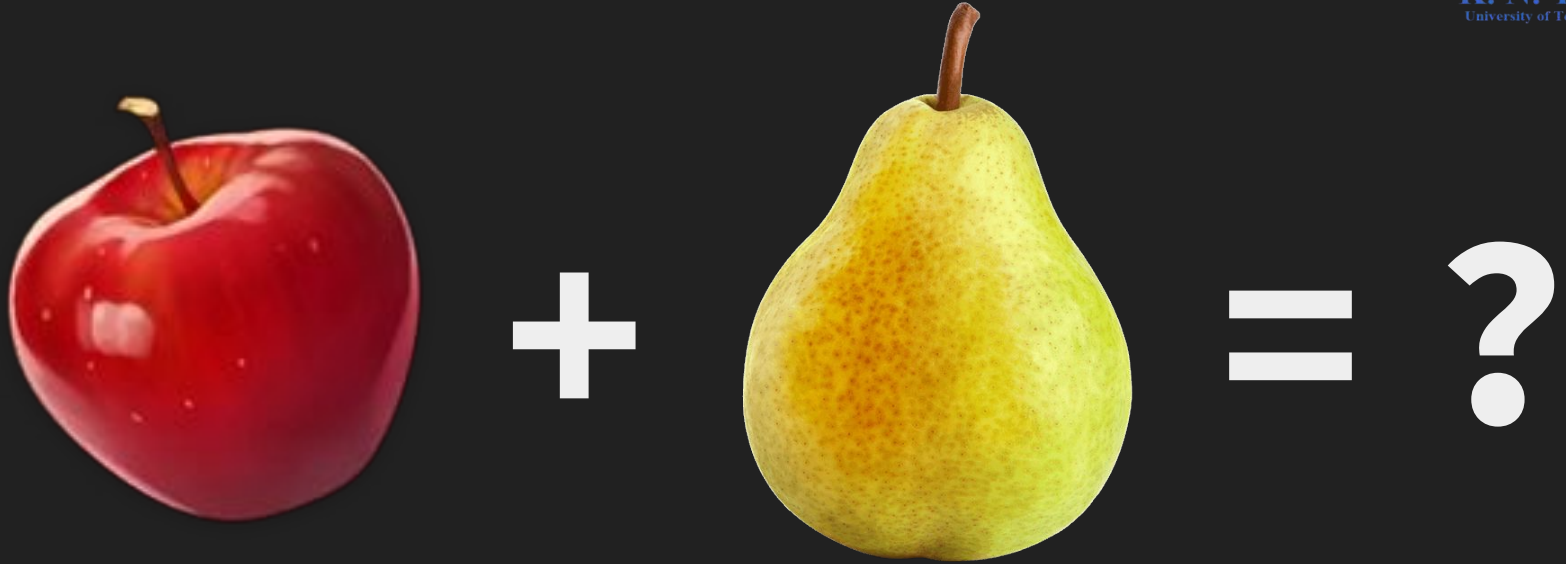


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Why bother? adding apples and pears?



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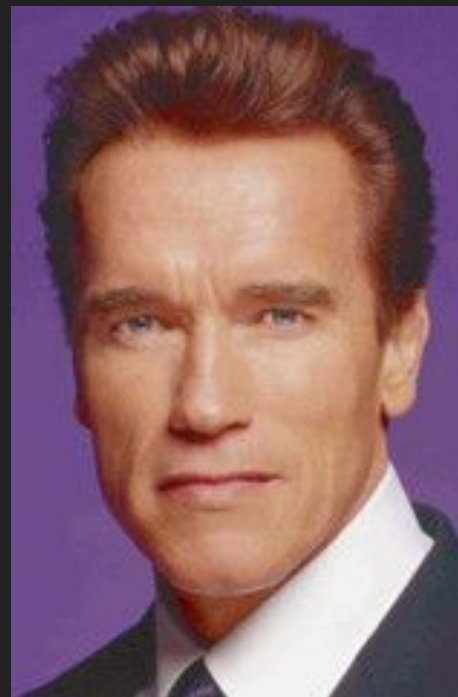
Why bother? Shape+Appearance Averaging



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Jerk



Cyborg

Why bother? Shape+Appearance Averaging



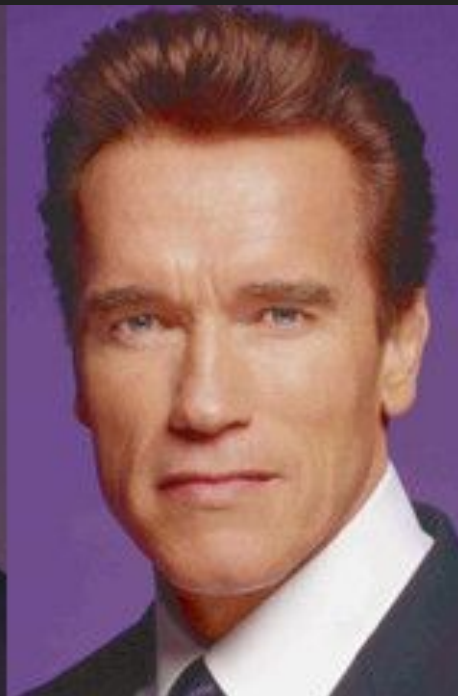
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Jerk



Cyjerk

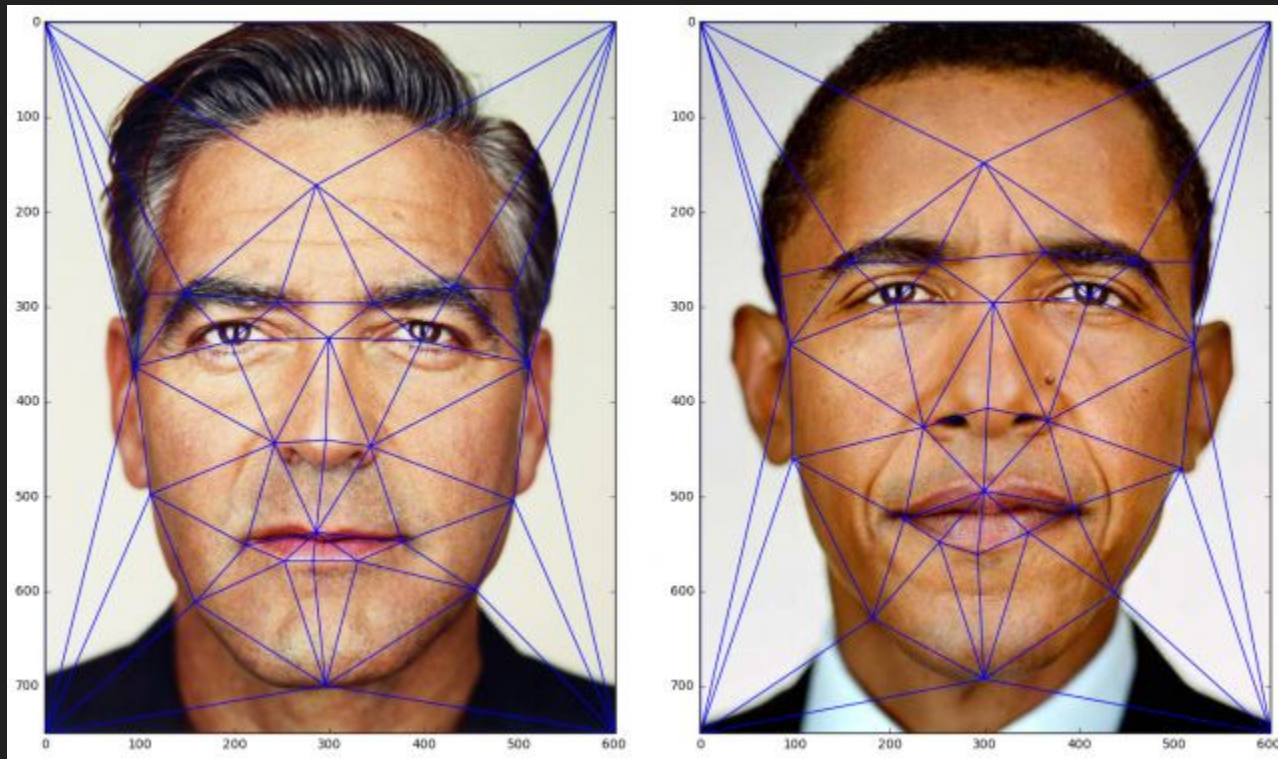


Cyborg

Why bother?



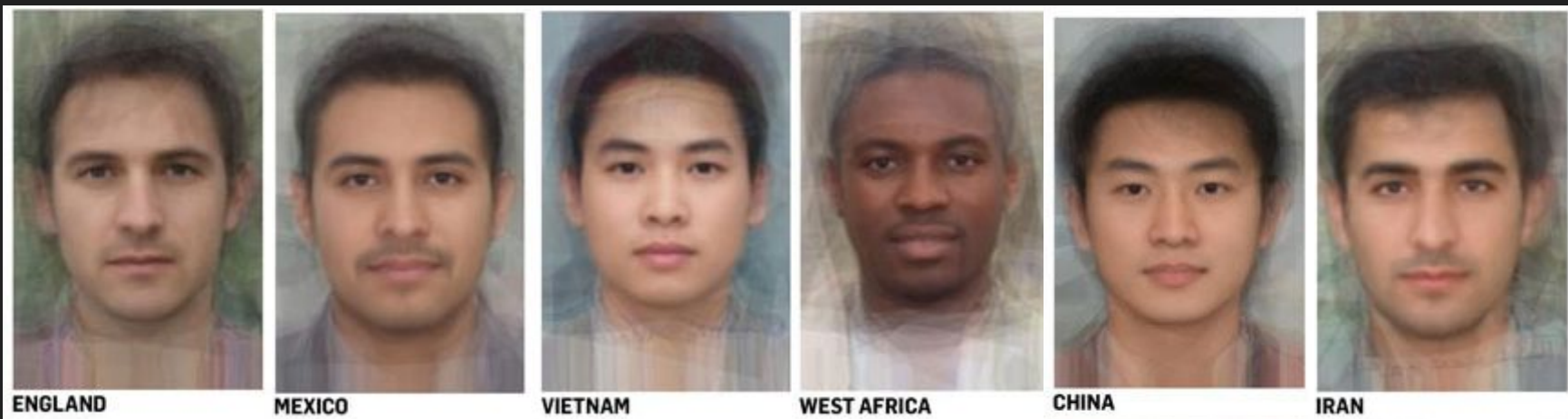
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Why bother? Average Faces by country



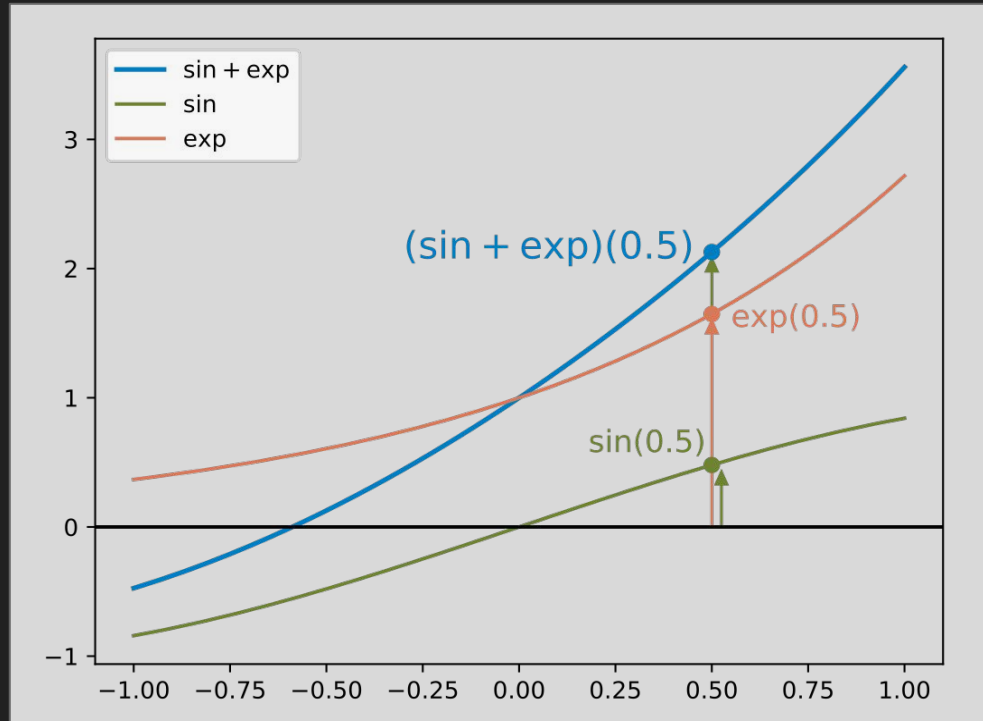
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Why bother? functions as vectors



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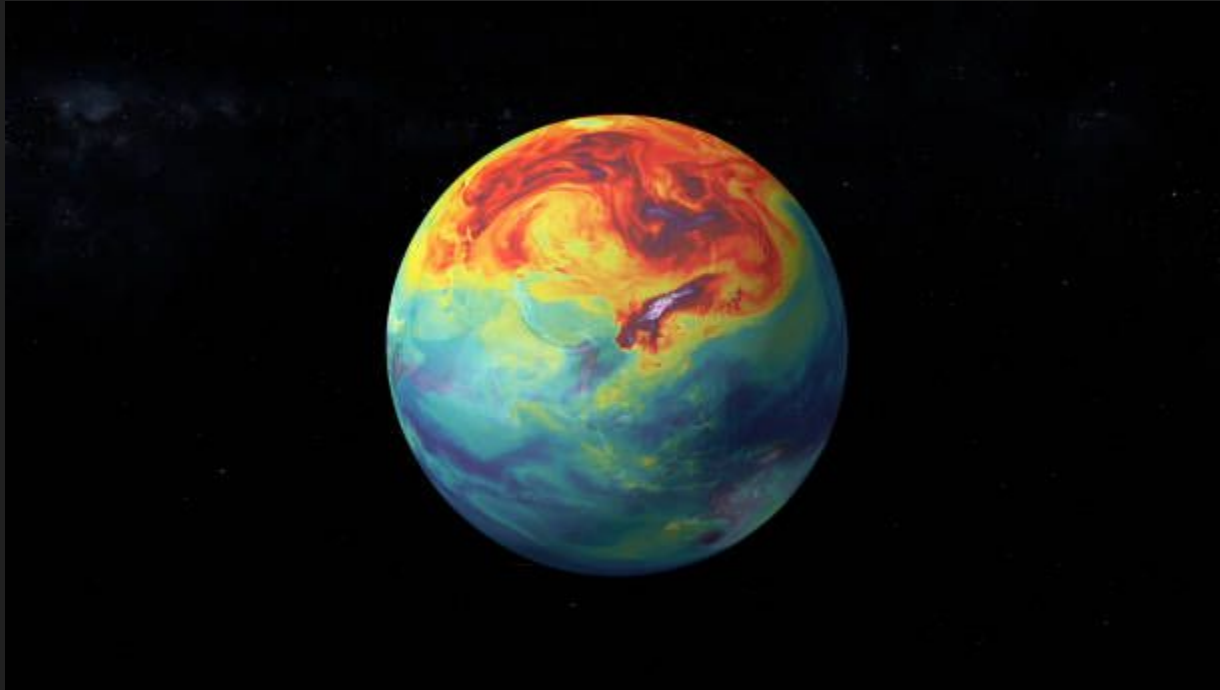


https://en.wikipedia.org/wiki/Vector_space

Why bother? functions as vectors



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What about non-Euclidean entities?



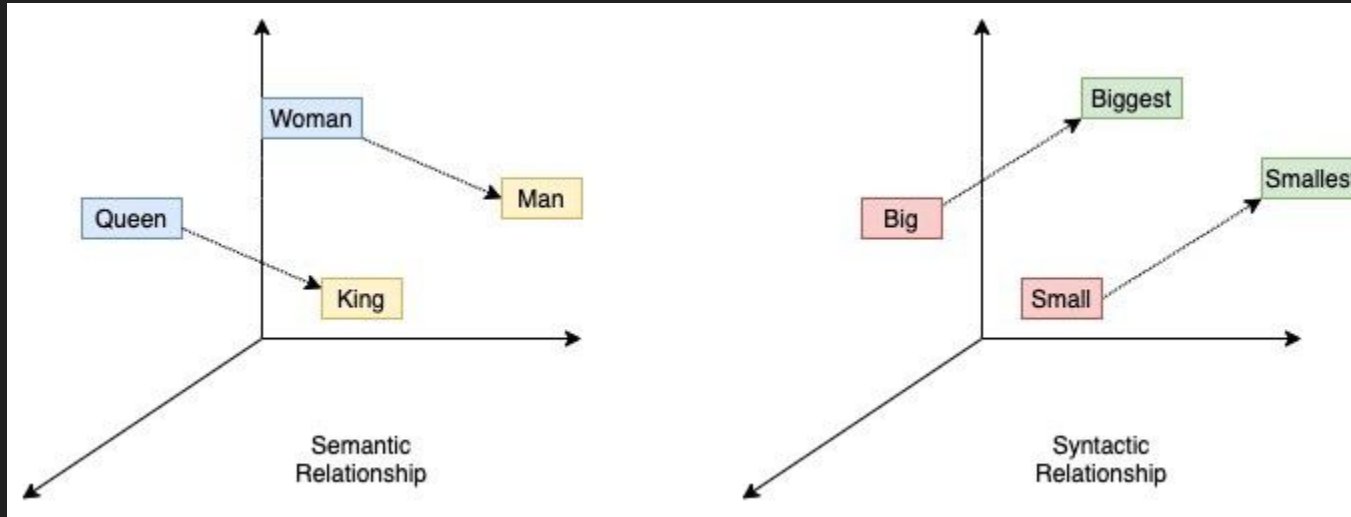
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- Words
- Graphs / Networks
- Entities defined on a nonlinear manifold
 - unit vectors
 - rotation matrices
 - lines/planes/subspaces
 - homogeneous vectors
- surfaces
- shapes (?)
- point clouds

What about non-Euclidean entities?



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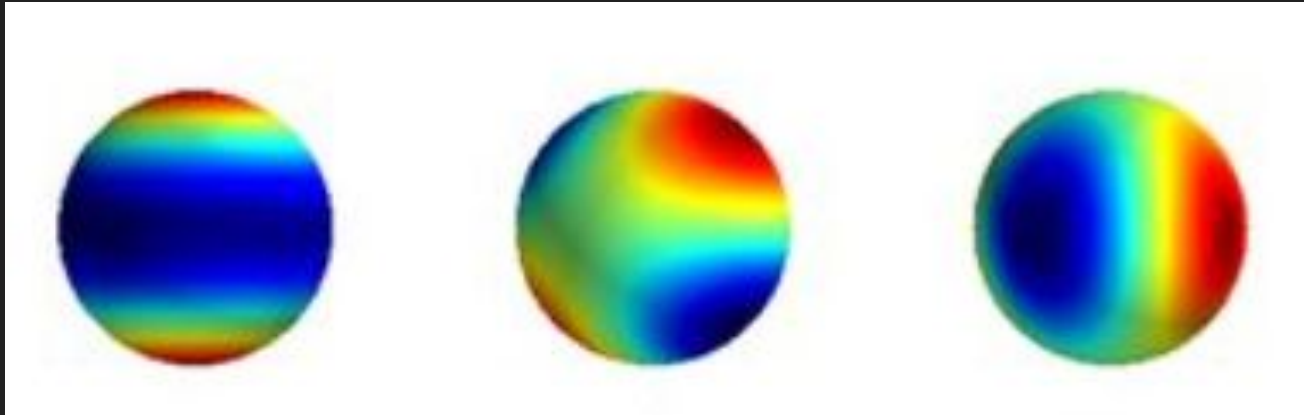


<https://towardsdatascience.com/word2vec-research-paper-explained-205cb7eccc30>

What about non-Euclidean entities?



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https://www.researchgate.net/publication/345372557_Efficient_HRTF_Representation_Using_Compact_Mode_HRTFs/figures?lo=1