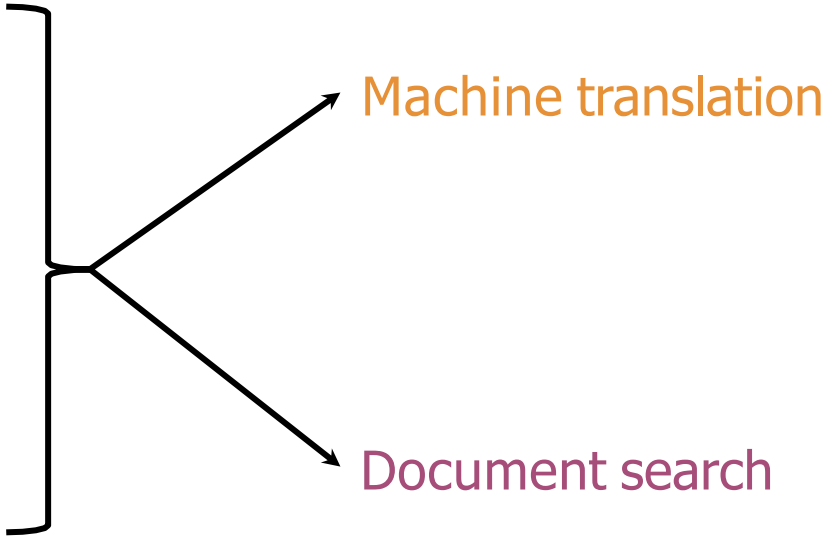
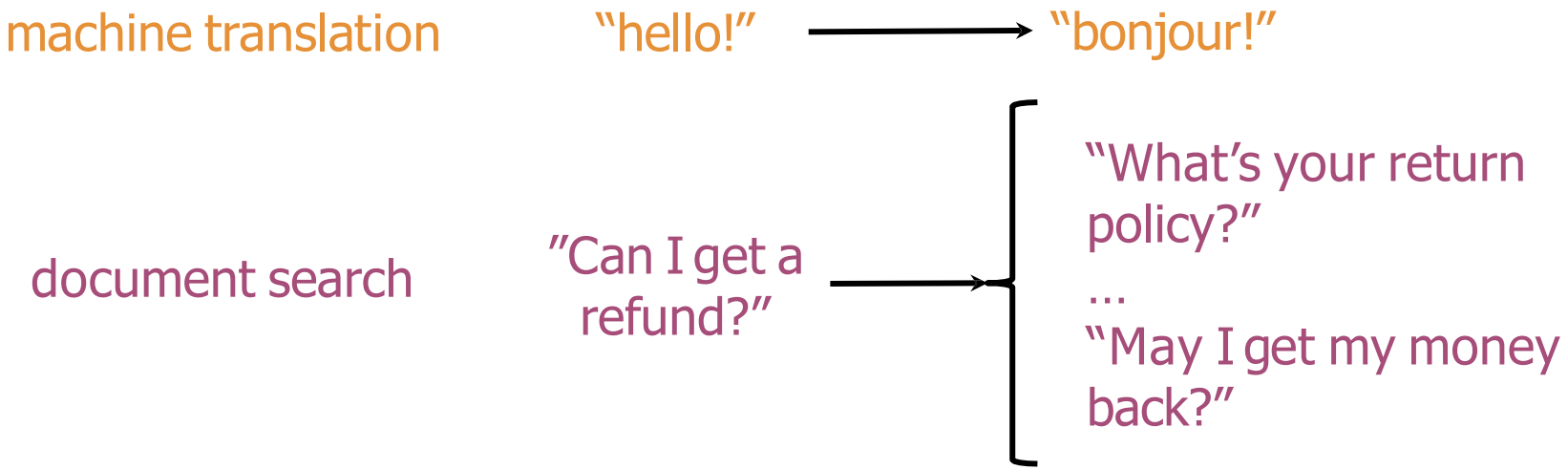
Machine Translation and Document Search

FPT Education
FPT UNIVERSITY

- Transform vector
- "K nearest neighbors"
- Hash tables
- Divide vector space into regions
- Locality sensitive hashing
- Approximated nearest neighbors



Overview-What you'll be able to do!

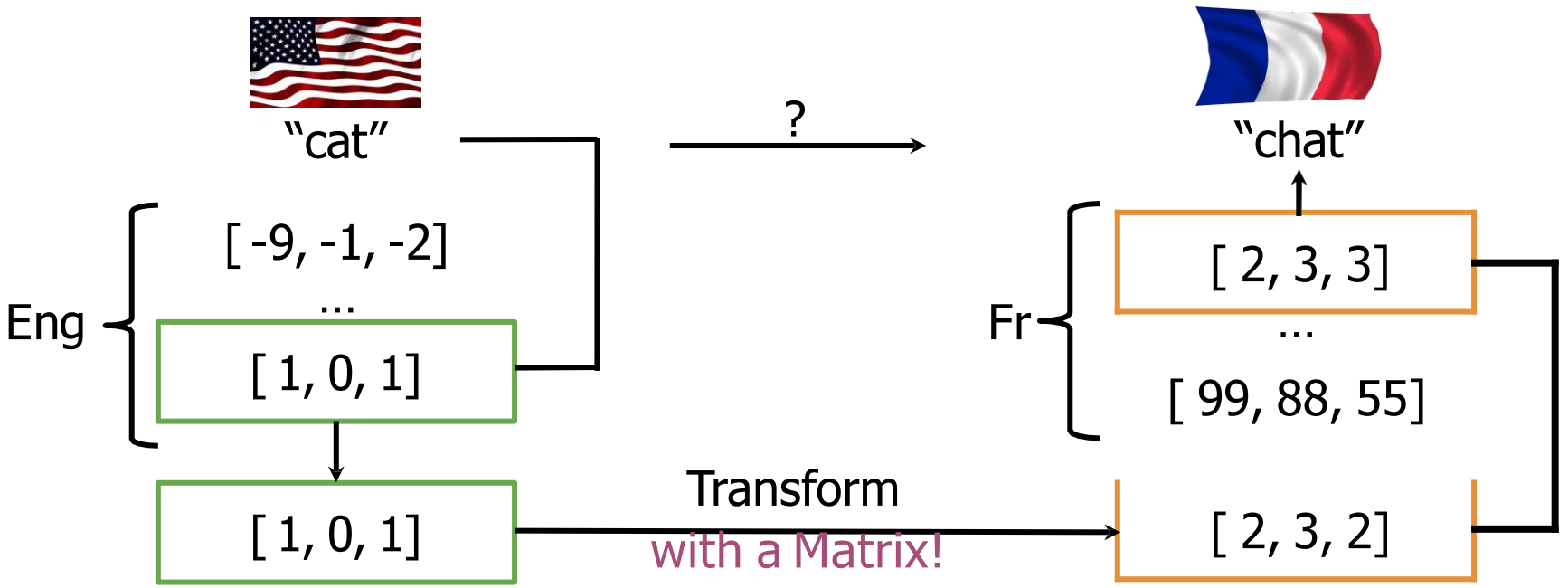


- Machine translation allows you to speak in one language and have your words translated into another
- It uses advanced algorithms and vast amounts of data to understand the nuances and subtleties of language, and
- It can even adapt to the unique way in which different individuals speak

Transforming word vectors

- Translation = Transformation
- How to get a good transformation

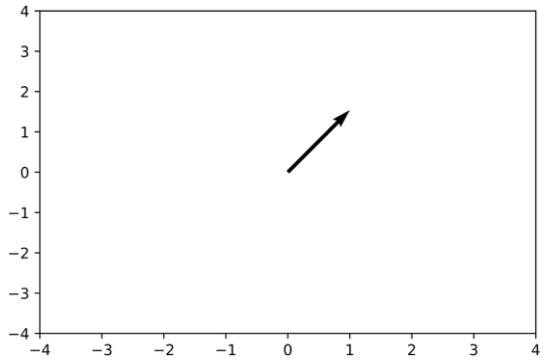
- Overview of Translation

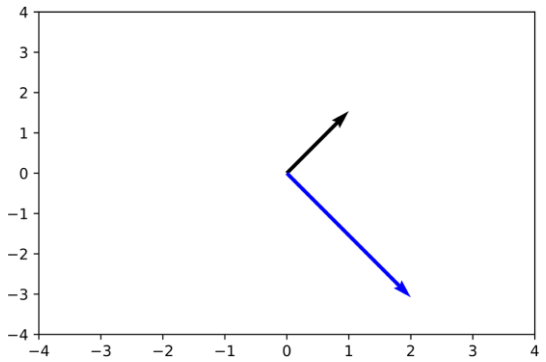


Transforming vectors

$$\begin{pmatrix}1 & 1\end{pmatrix}\begin{pmatrix}2 & 0\\ 0 & -2\end{pmatrix}=\begin{pmatrix}2 & -2\end{pmatrix}$$

X R Y



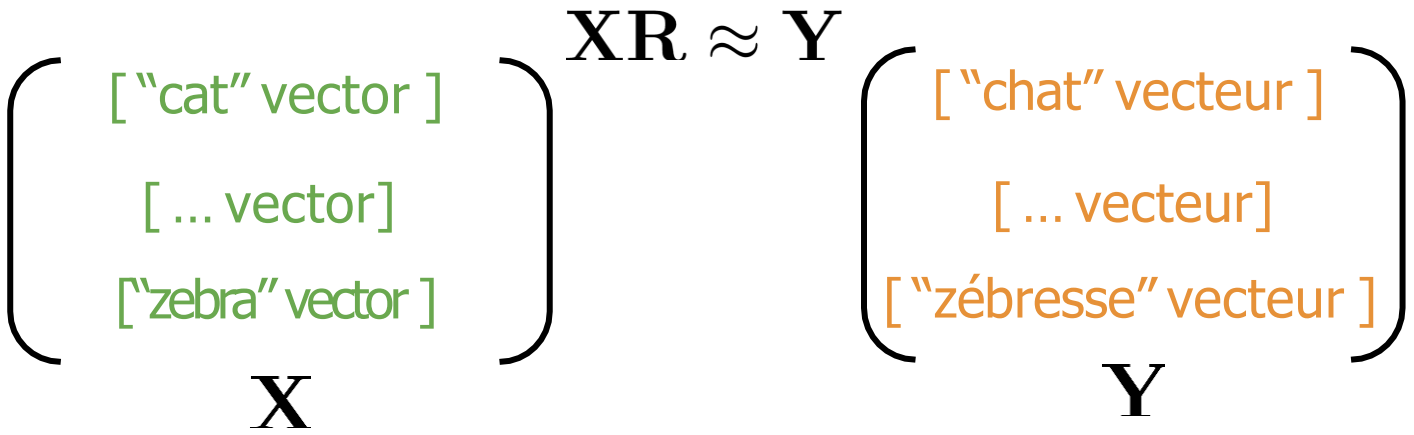



```
R = np.array([[2,0],


x = np.array([[1,1]])

np.dot(x,R)
```

```
array([[2,-2]])
```

Try it yourself!

Align word vectors



subsets of the full vocabulary

Solving for R

initialize R

in a loop:

$$Loss = \| \mathbf{XR} - \mathbf{Y} \|_F$$

$$g = \frac{d}{dR} Loss$$ gradient

$$R = R - \alpha g$$ update

Frobenius norm

$$\| \mathbf{XR} - \mathbf{Y} \|_F$$

$$\mathbf{A} = \begin{pmatrix} 2 & 2 \\ 2 & 2 \end{pmatrix}$$

$$\|\mathbf{A}_F\| = \sqrt{2^2 + 2^2 + 2^2 + 2^2}$$

$$\|\mathbf{A}_F\| = 4$$

$$\|\mathbf{A}\|_F \equiv \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} |a_{ij}|^2}$$


```
A = np.array([[2,2],[2,2]])
A_squared = np.square(A)
A_squared
```

```
array([[4,4],[4,4]])
```

```
A_Frobenious = np.sqrt(np.sum(A_squared))
A_Frobenious
```

```
4.0
```

Frobenius norm squared

$$\|\mathbf{XR} - \mathbf{Y}\|_F^2$$

$$\mathbf{A} = \begin{pmatrix} 2 & 2 \\ 2 & 2 \end{pmatrix}$$

$$\|\mathbf{A}\|_F^2 = \left(\sqrt{2^2 + 2^2 + 2^2 + 2^2}\right)^2$$

$$\|\mathbf{A}\|_F^2 = 16$$

Gradient

$$Loss = \|\mathbf{XR} - \mathbf{Y}\|_F^2$$

$$g = \frac{d}{dR} Loss = \frac{2}{m}\left(\mathbf{X}^T(\mathbf{XR} - \mathbf{Y})\right)$$

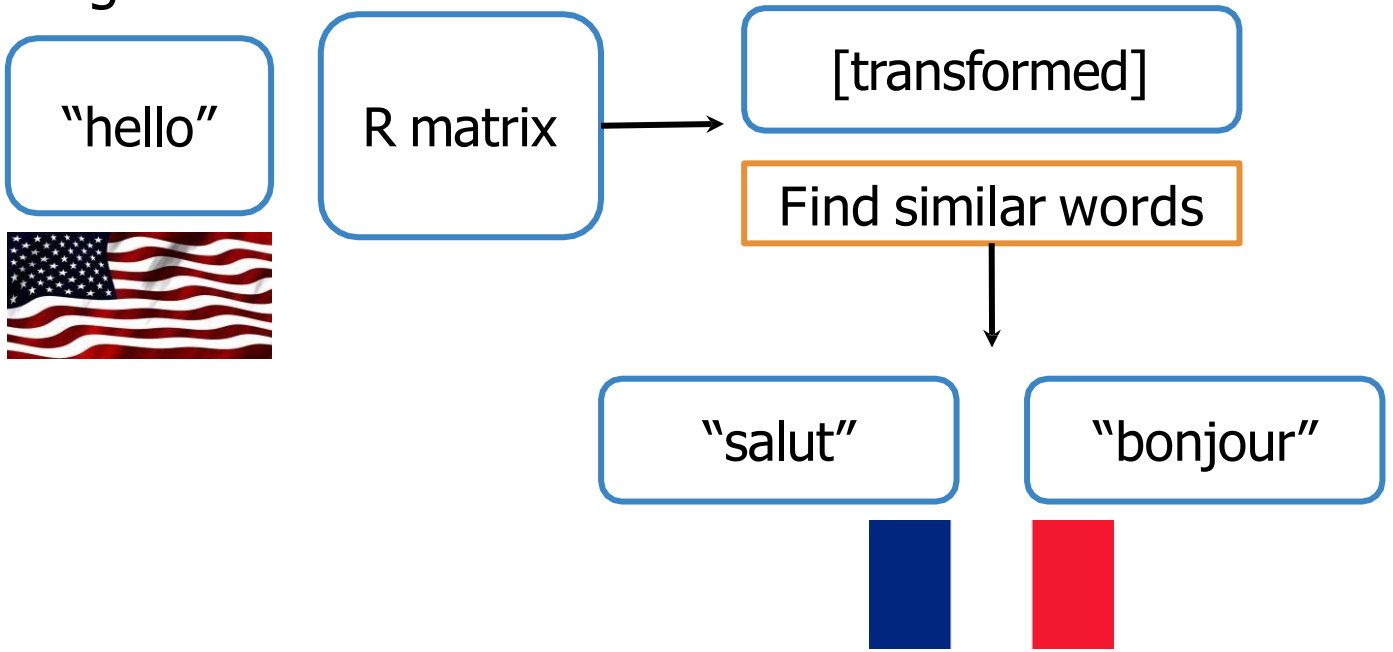
Summary

- $\mathbf{XR} \approx \mathbf{Y}$
- minimize $\|\mathbf{XR} - \mathbf{Y}\|_F^2$

K-nearest neighbors

- K closest matches ⟶ K-nearest neighbors

- Finding the translation

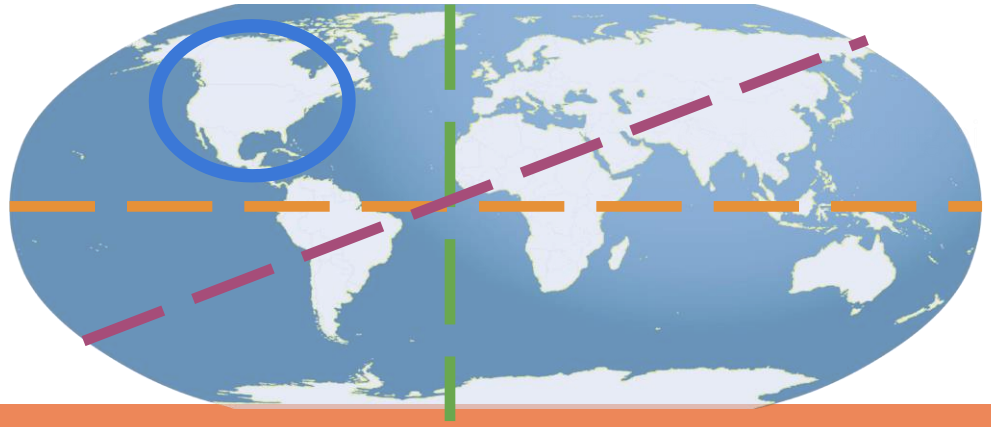


Nearest neighbours

You

San Francisco

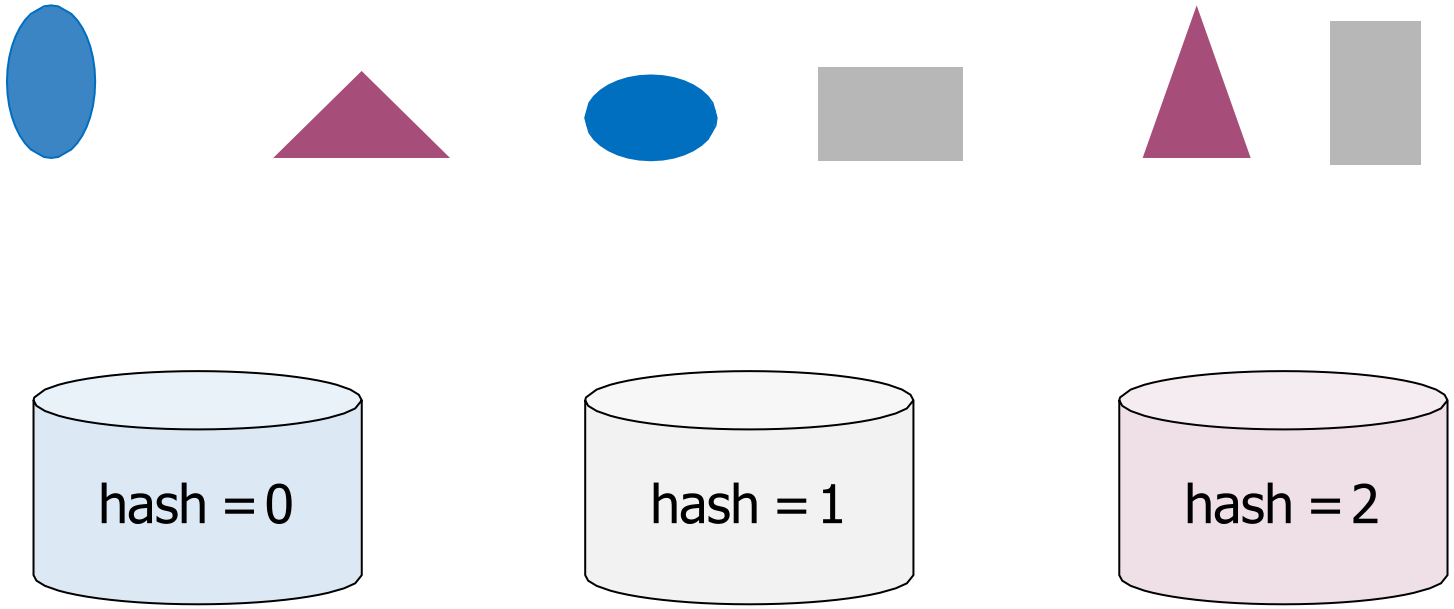
Friend	Location	Nearest
	Shanghai	2
	Bangalore	3
	Los Angeles	1



Hash tables!

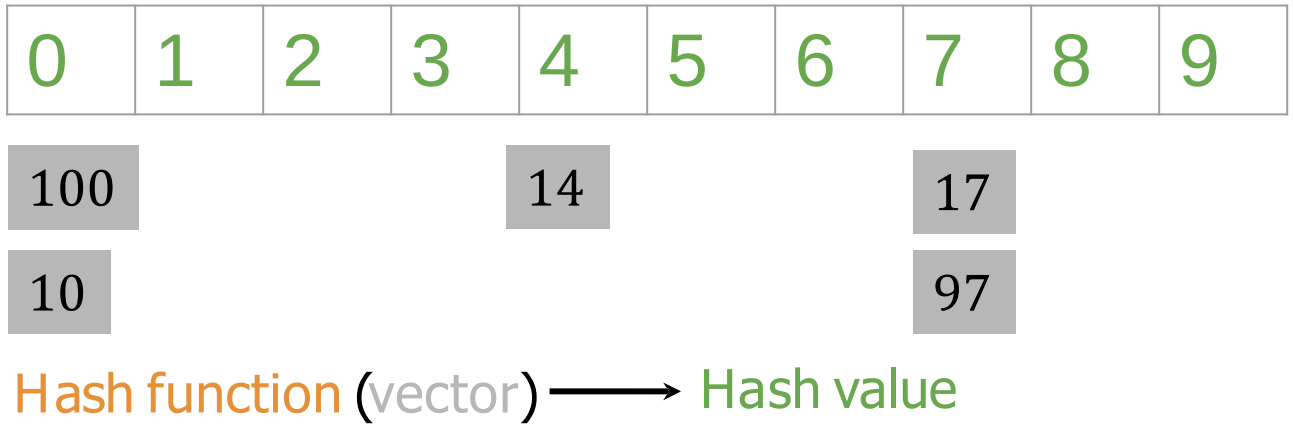
Hash tables and hash functions

- A hash function maps an object to a bucket in a hash table
- Hash tables



Hash function

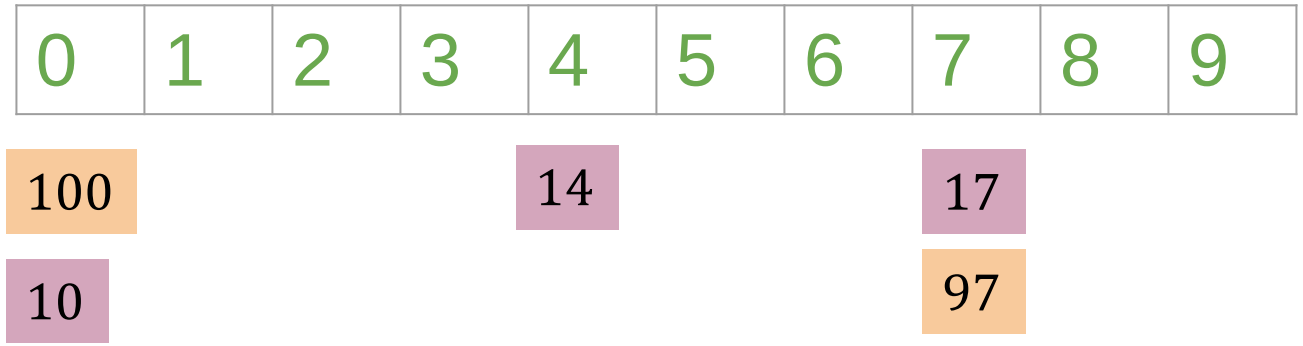
- A simple hash function : Hash Value = vector % number of buckets



Create a basic hash table

```
def basic_hash_table(value_l,n_buckets):

    def hash_function(value_l,n_buckets):
            return int(value_l) % n_buckets

    hash_table = {i:[] for i in range(n_buckets)}
    for value in value_l:
            hash_value =
hash_function(value,n_buckets)

    return hash_table
```

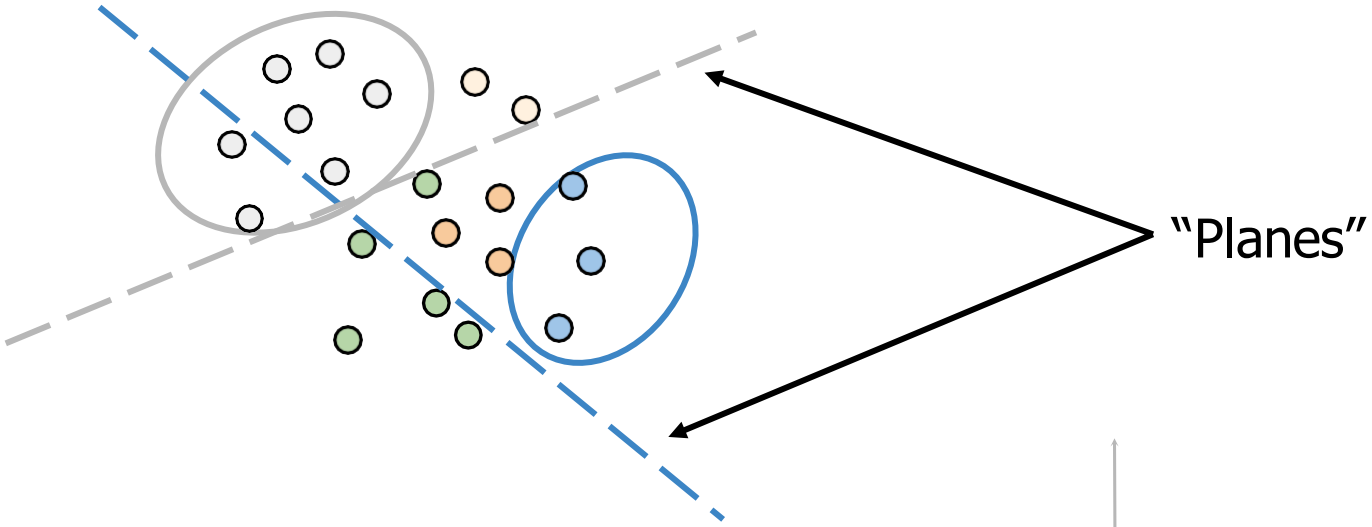
Hash function

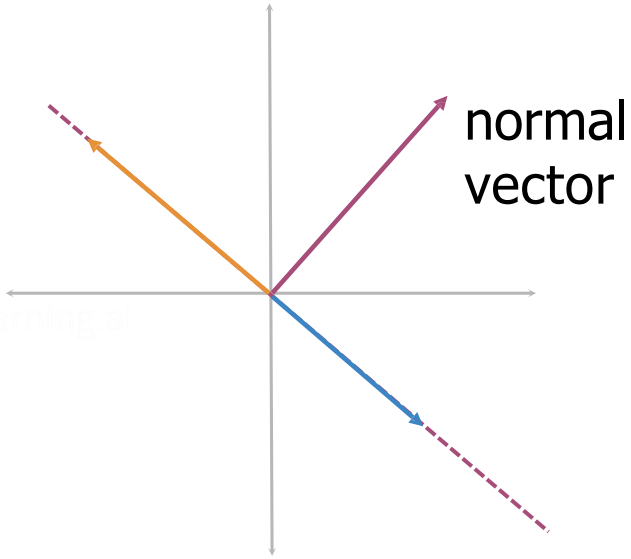


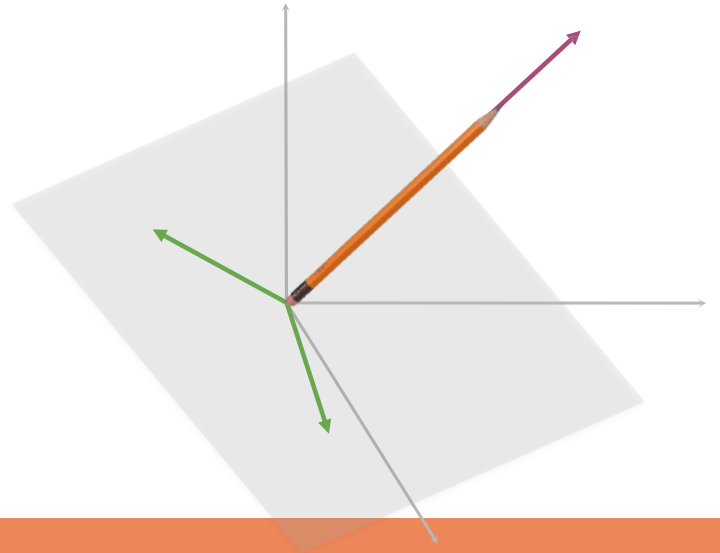
Hash function by location?

Locality sensitive hashing, next!

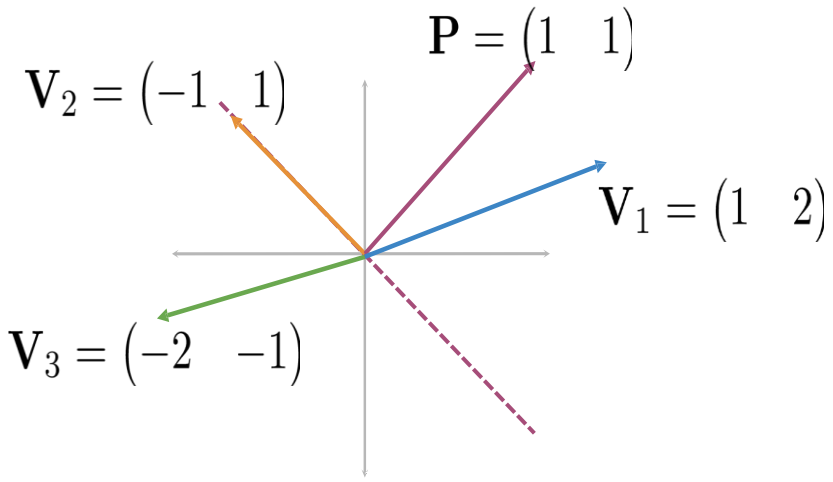
Locality Sensitive Hashing

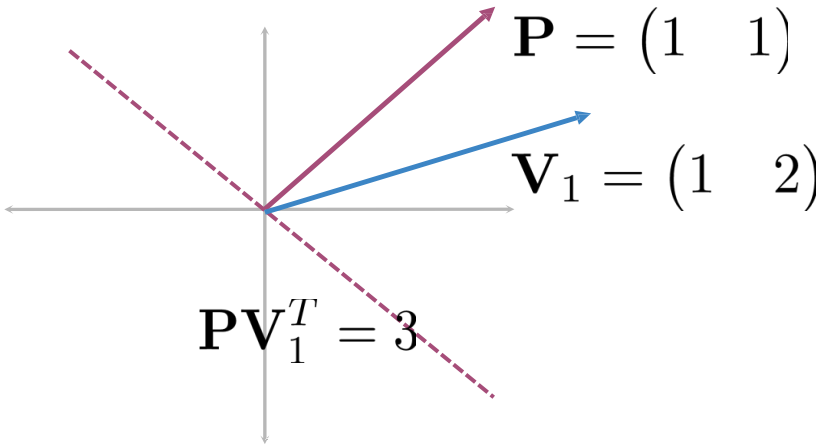


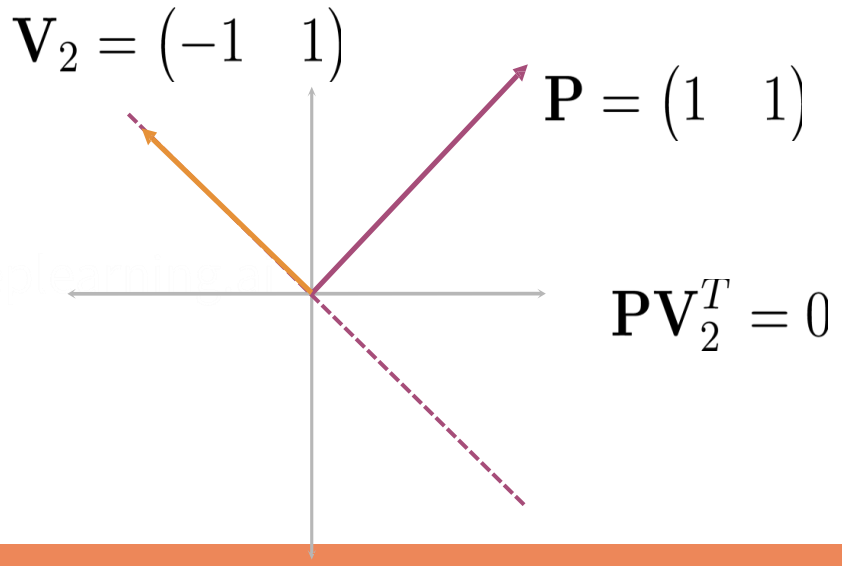


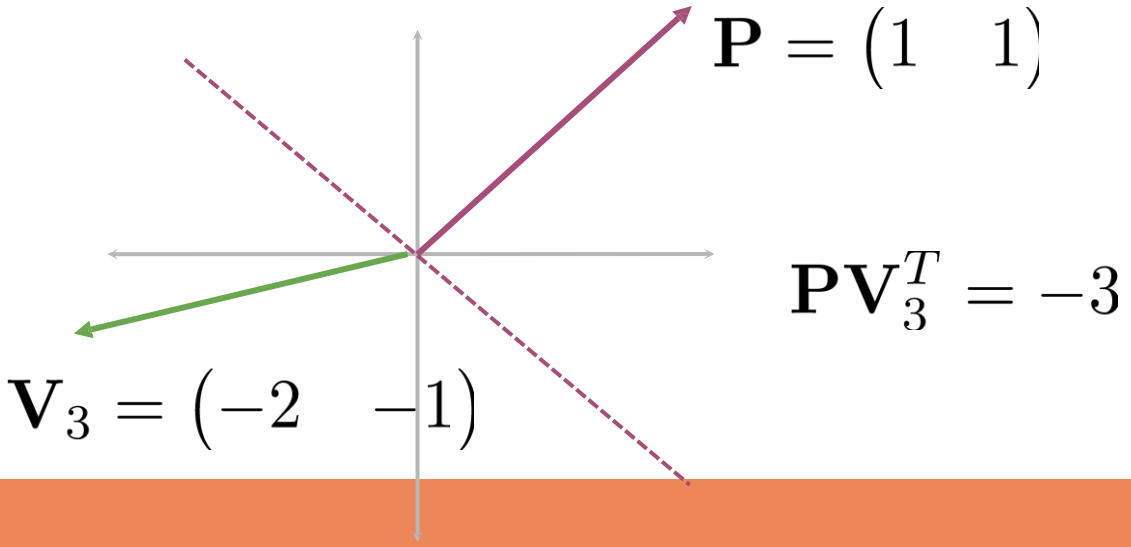


Which side of the plane?

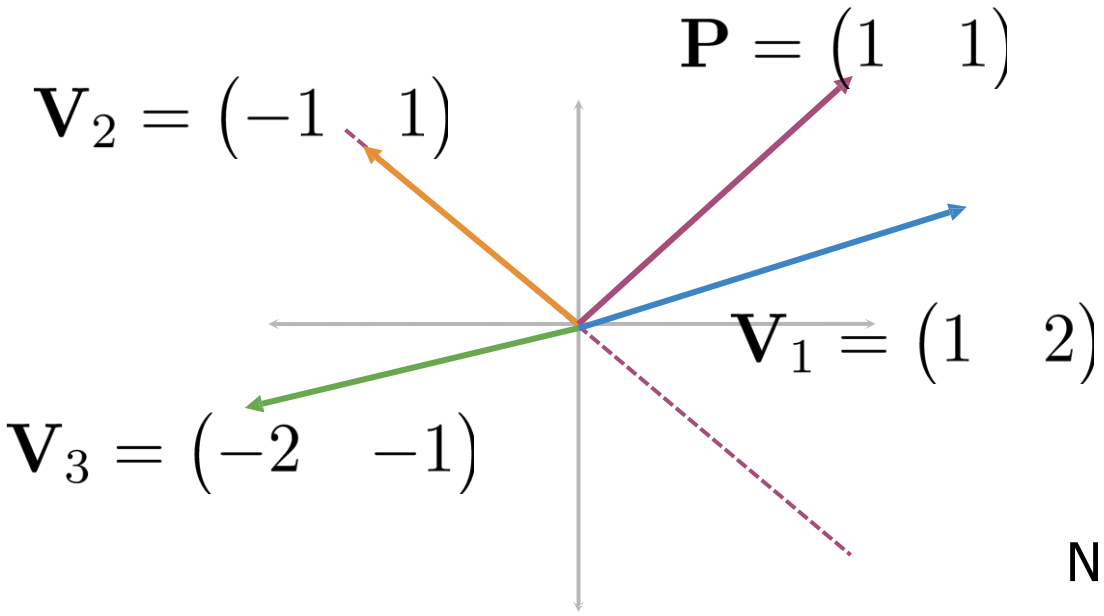








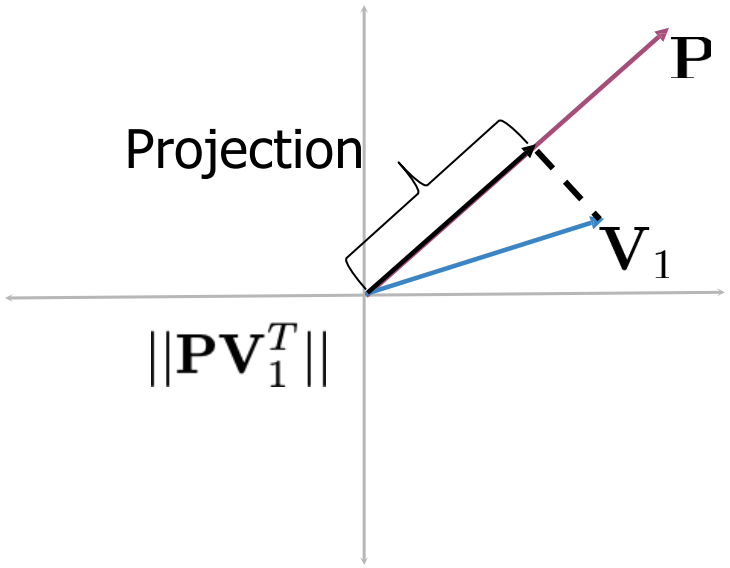
Which side of the plane?

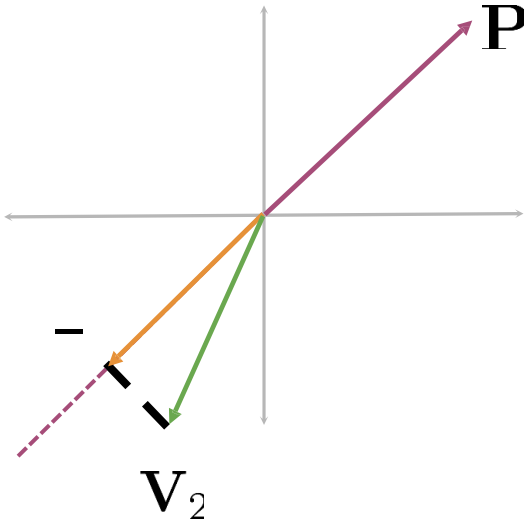


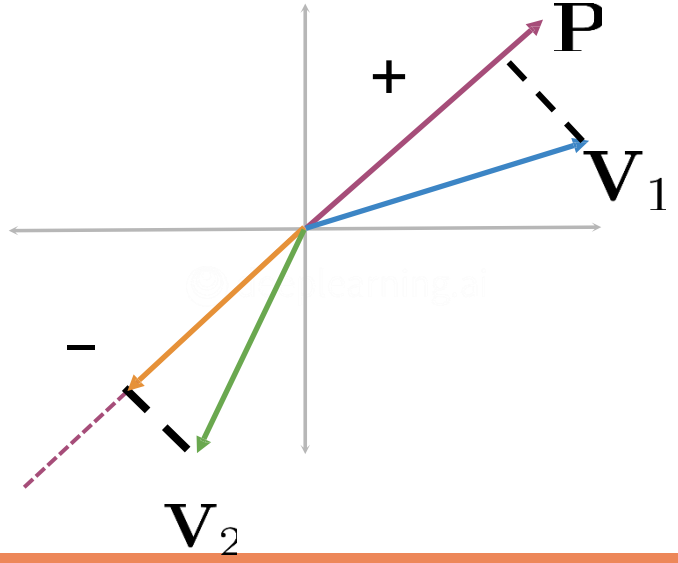
$$\mathbf{P}\mathbf{V}_1^T = 3$$
$$\mathbf{P}\mathbf{V}_2^T = 0$$
$$\mathbf{P}\mathbf{V}_3^T = -3$$

Notice the signs?

Visualizing a dot product







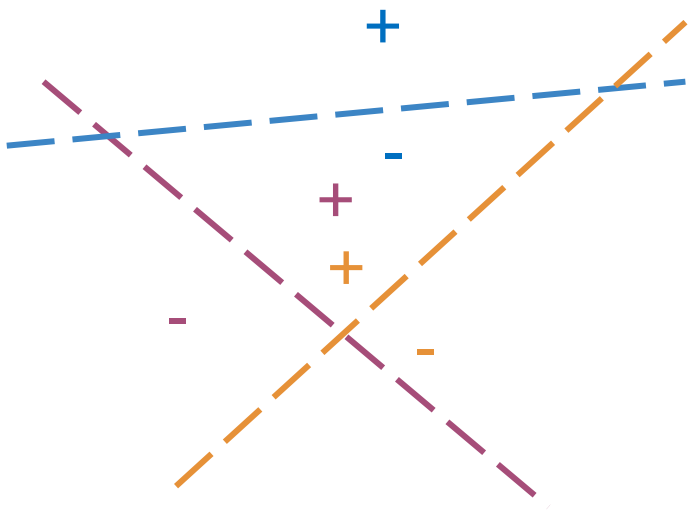
Sign indicates direction

Which side of the plane?

```
def side_of_plane(P,v):
    dotproduct = np.dot(P,v.T)
    sign_of_dot_product = np.sign(dotproduct)
    sign_of_dot_product_scalar= np.asscalar(sign_of_dot_product)
    return sign_of_dot_product_scalar
```

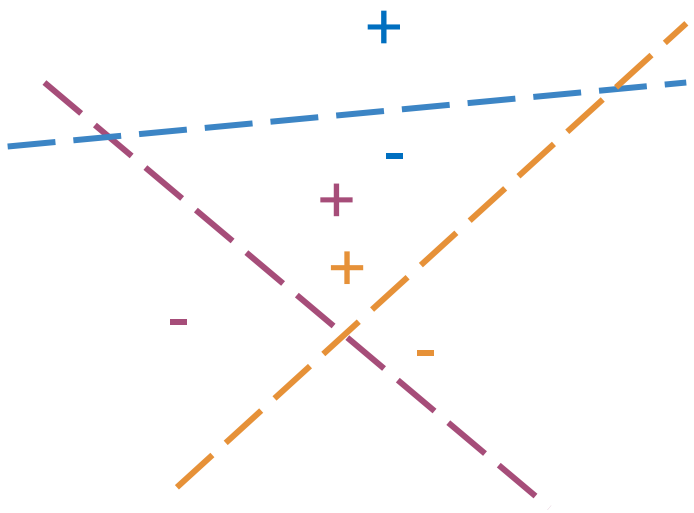
Try it!

Multiple planes



single hash value?

Multiple planes, single hash value?



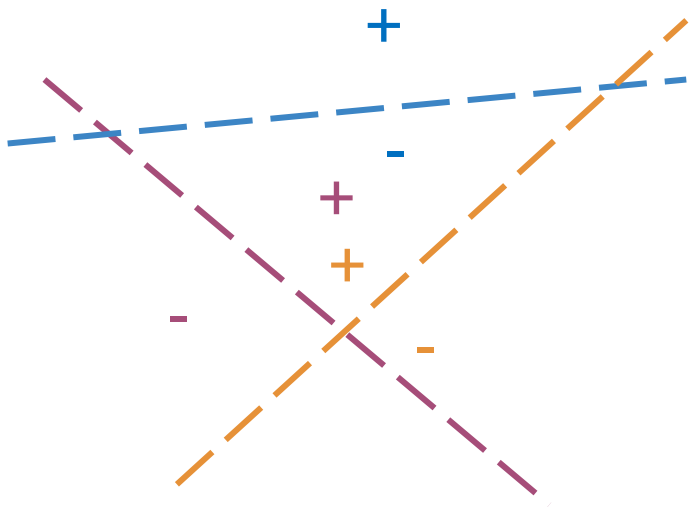
$$\mathbf{P}_1\mathbf{v}^T = 3, sign_1 = +1, h_1 = 1$$

$$\mathbf{P}_2\mathbf{v}^T = 5, sign_2 = +1, h_2 = 1$$

$$\mathbf{P}_3\mathbf{v}^T = -2, sign_3 = -1, h_3 = 0$$

$$\begin{aligned} hash &= 2^0 \times h_1 + 2^1 \times h_2 + 2^2 \times h_3 \\ &= 1 \times 1 + 2 \times 1 + 4 \times 0 \\ &= 3 \end{aligned}$$

Multiple planes, single hash value!



$$sign_i \geq 0, \rightarrow h_i = 1$$

$$sign_i < 0, \rightarrow h_i = 0$$

$$\text{hash} = \sum_{i}^{H} 2^i \times h_i$$

Multiple planes, single hash value!!

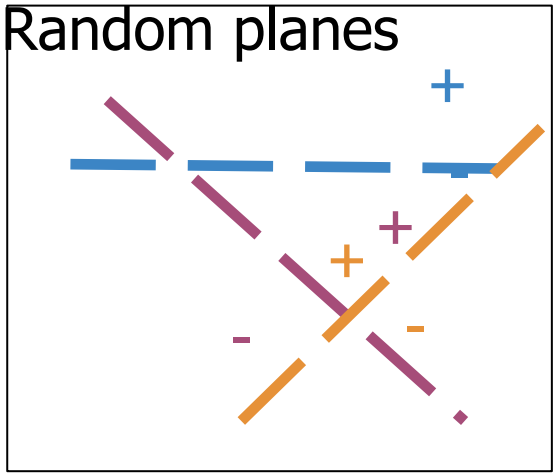
```
def hash_multiple_plane(P_l,v):

    hash_value = 0

    for i, P in enumerate(P_l):
        sign = side_of_plane(P,v)
        hash_i = 1 if sign >=0 else 0
        hash_value += 2**i * hash_i

    return hash_value
```

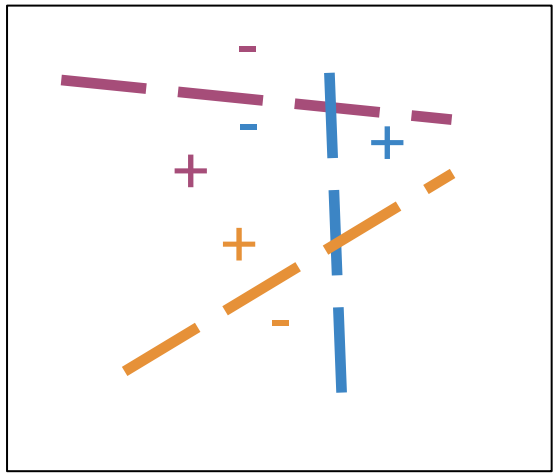
Try it!

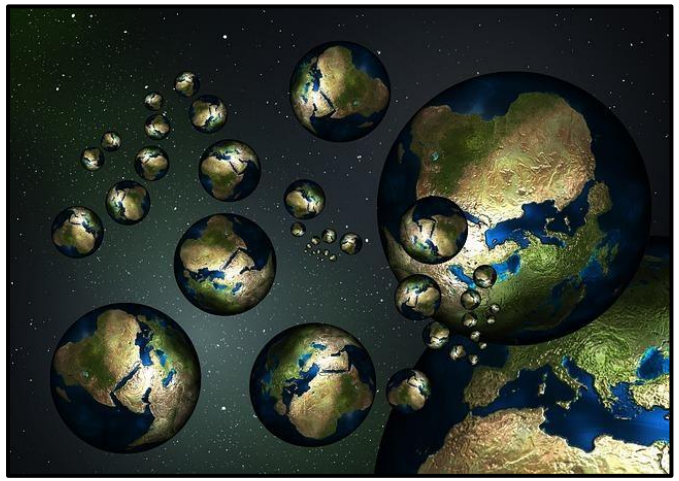
Approximate nearest neighbors

- Multiple sets of planes for approximate K-nearest neighbors

- Random planes

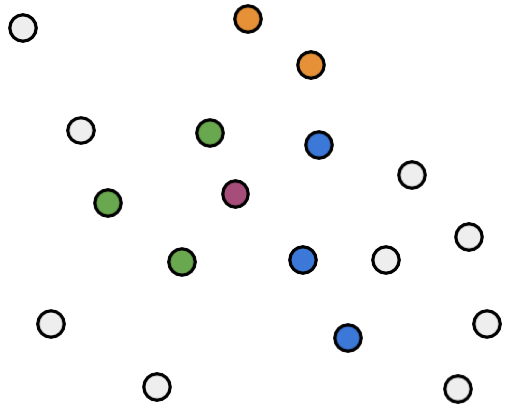






Cultural reference: Spider-Man: Into the Spider-Verse

Multiple sets of random planes



Approximate nearest
(friendly) neighbors

Make one set of random planes

```
num_dimensions = 2 #300 in assignment
num_planes = 3 #10 in assignment

random_planes_matrix = np.random.normal(
                       size=(num_planes,
                             num_dimensions))
```

```
array([[ 1.76405235  0.40015721]
       [ 0.97873798  2.2408932 ]
       [ 1.86755799 -0.97727788]])
```

```
v = np.array([[2,2]])
```

```
def side_of_plane_matrix(P,v):
          dotproduct = np.dot(P,v.T)
          sign_of_dot_product =
np.sign(dotproduct)

num_planes_matrix = side_of_plane_matrix(
                    random_planes_matrix,v)
```

```
array([[1.]
       [1.]
       [1.])
```

See notebook for calculating the hash value!

Searching documents

- Representation for documents
- Document search with K-nearest neighbors

- Document representation

I love learning!	[?, ?, ?]
I	[1, 0, 1]
+	
love	[-1, 0, 1]
+	
learning	[1, 0, 1]
=	
I love learning!	[1, 0, 3]

Document Search

K-NN!

Document vectors

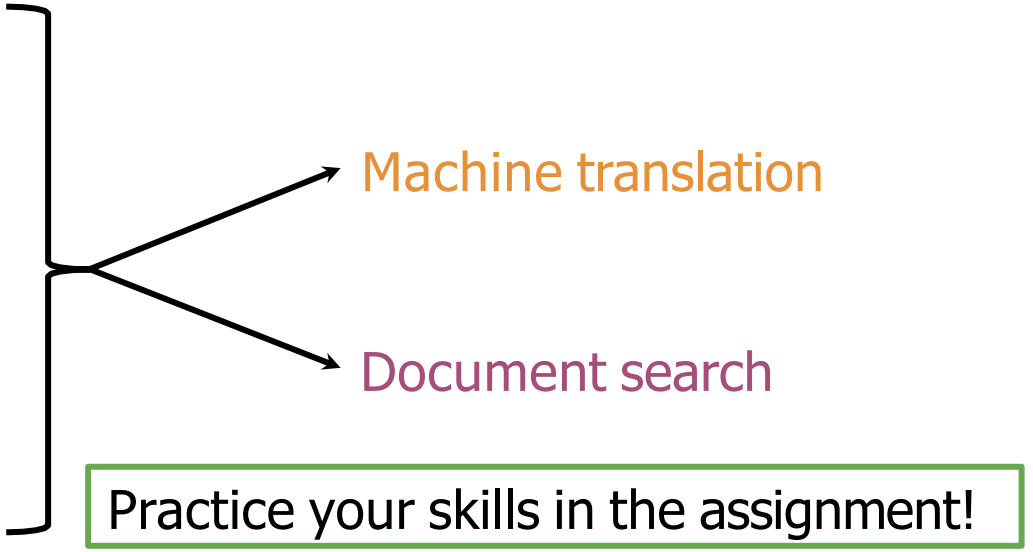
```
word_embedding = {“I”: np.array([1,0,1]),
                  “love”: np.array([-1,0,1]),
                  “learning”: np.array([1,0,1])}

words_in_document = [‘I’, ‘love’, ‘learning’]

document_embedding = np.array([0,0,0])

for word in words_in_document:
        document_embedding +=

print(document_embedding)
```

```
array([1 0 3])
```

Try it!

Revisit Learning Objectives

- Transform vector
- "K nearest neighbors"
- Hash tables
- Divide vector space into regions
- Locality sensitive hashing
- Approximated nearest neighbors



Practice your skills in the assignment!