Final Year Project

2017-2018

Group 31
Review 2

Brain

Computer

Interface

SSVEP Classification

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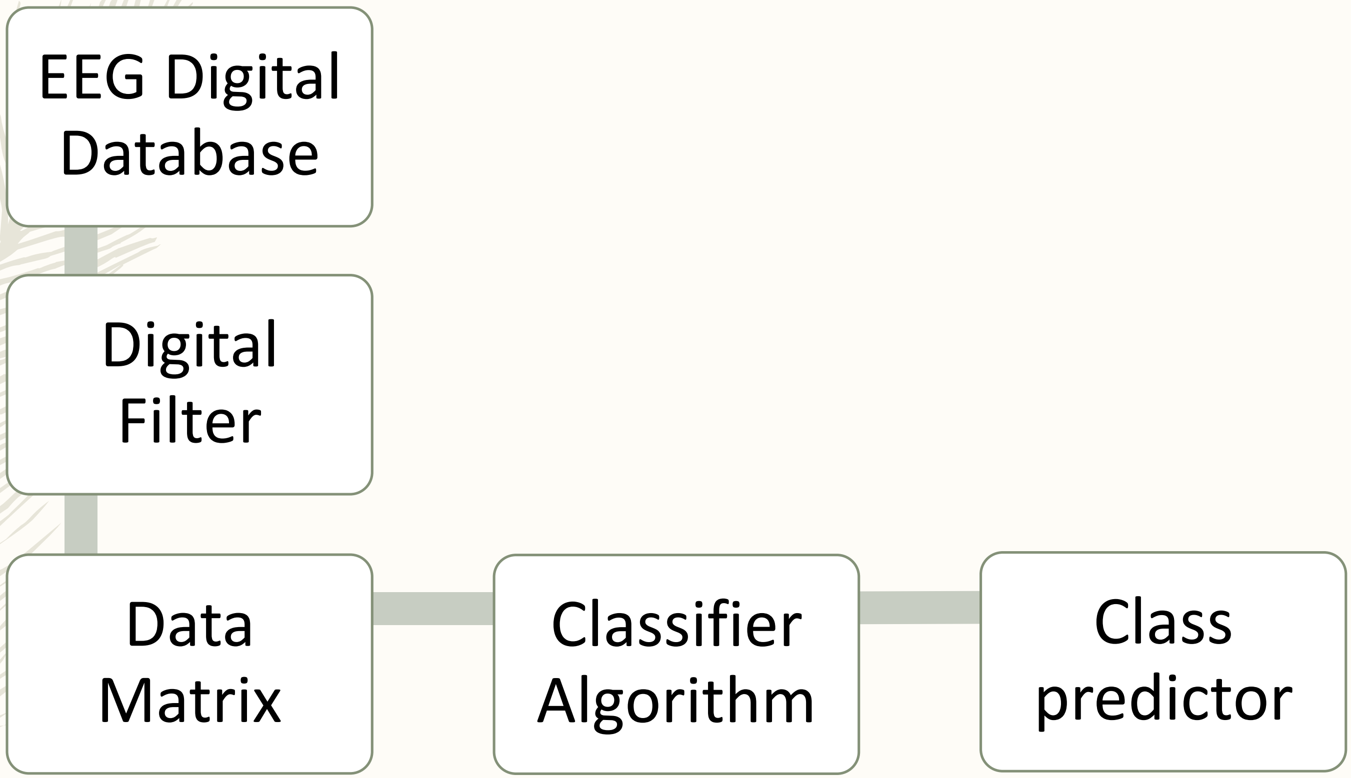
THE OBJECTIVE

Classify EEG signals in an SSVEP using a statistical approach

- SSVEP classification
- Statistical Approach
- Using our own data set
- Explore a Riemann manifold approach
  - What is it?
  - Why is it better than the conventional CCA?
- Benefits
  - Minimised search so faster detection possible theoretically.
  - Covariance estimation and distance metric dependencies.
    - Fine tuning possible
    - Double edged sword, however

Offline SSVEP Classification



The Data

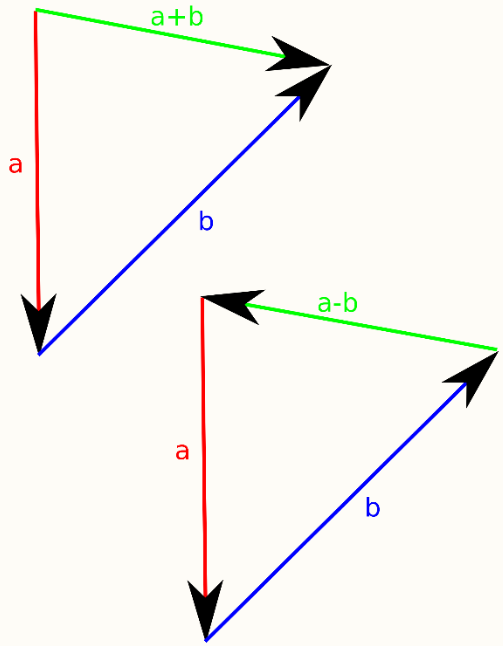
$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \Rightarrow \begin{bmatrix} c_{11} & \cdots & c_{1m} \\ \vdots & \ddots & \vdots \\ c_{m1} & \cdots & c_{mm} \end{bmatrix}$$

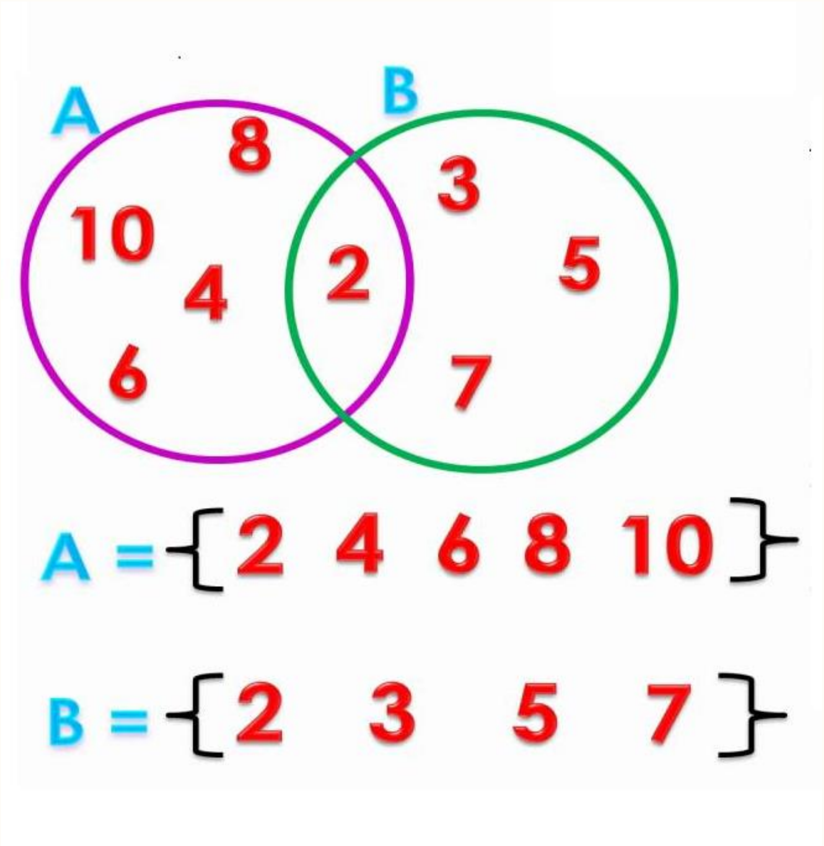
EEG Data

Covariance Matrix

- There are different ways to compute the covariance matrix
- Each of the methods have different computation costs and accuracy
- Each covariance matrix is a point on an $\frac{m(m+1)}{2}$ dimensional riemannian surface

What is a vector?





Ordered Set

$$\{1,2,3,4,5,6\} \quad \mathit{Different\ From} \quad \{3,1,4,2,6,5\}$$

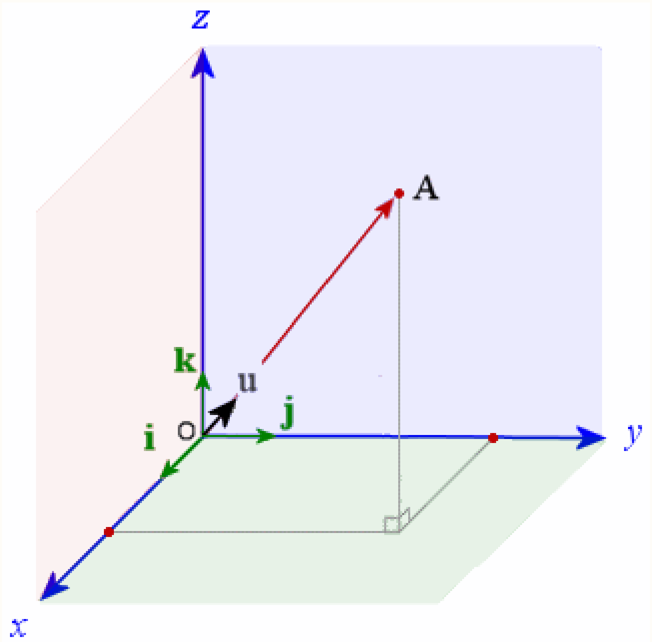
$$\begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{bmatrix} \quad \mathit{Different\ From} \quad \begin{bmatrix} 3 \\ 1 \\ 4 \\ 2 \\ 6 \\ 5 \end{bmatrix}$$

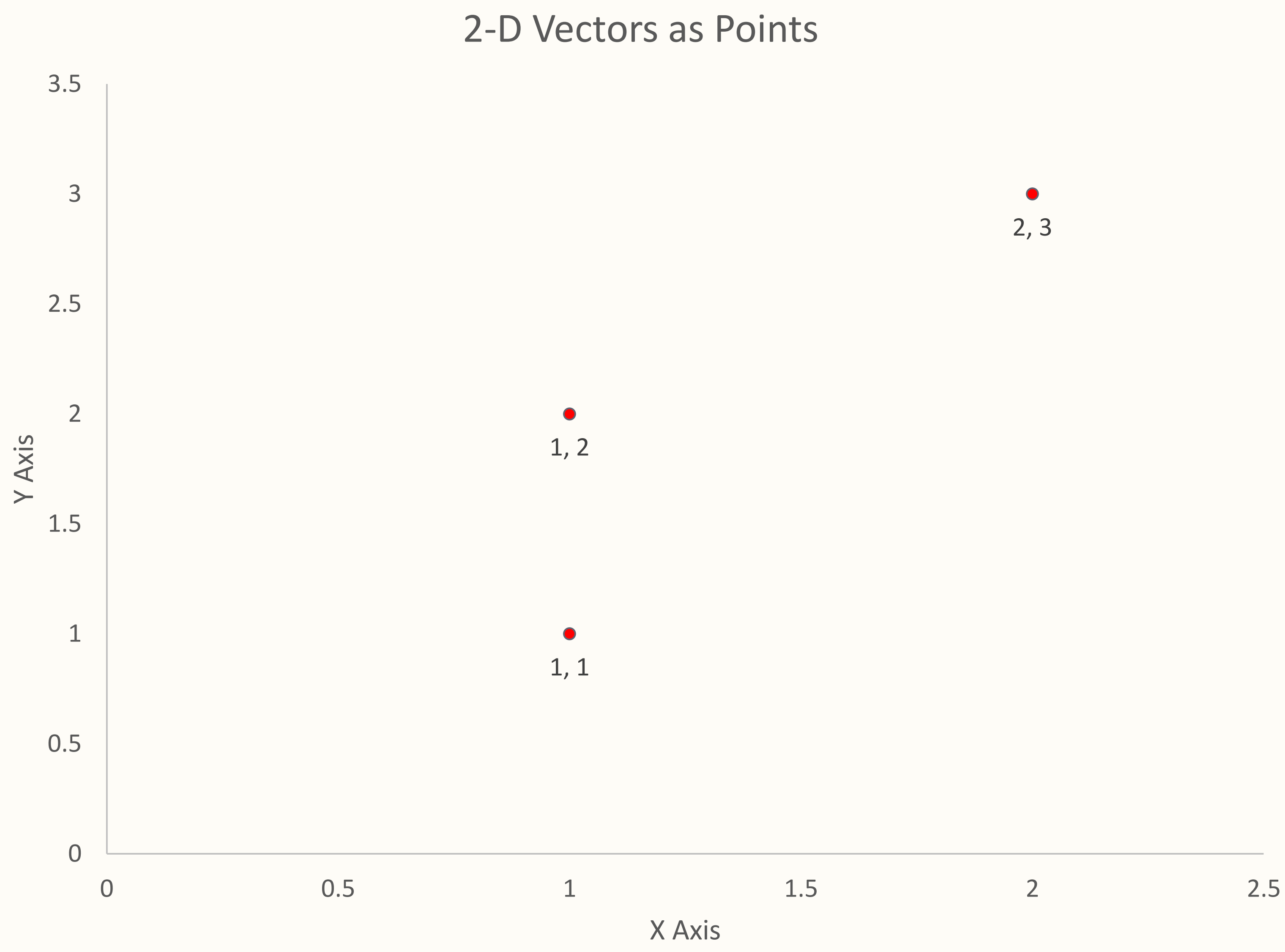
Geometric Representation

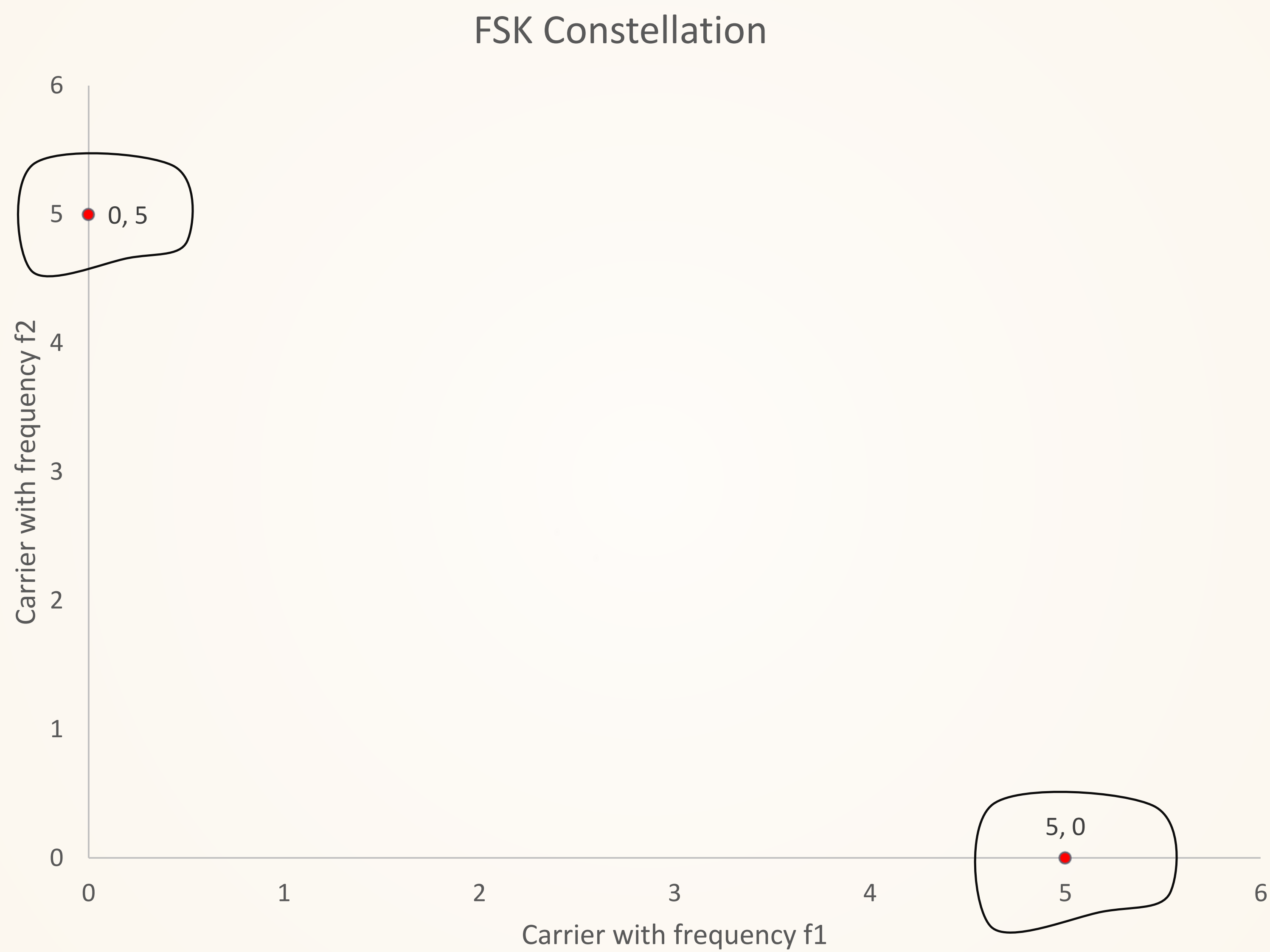
$$\begin{bmatrix} 1 & 1 & 2 \\ 0 & -6 & 2 \\ 1 & 3 & 4 \end{bmatrix}$$

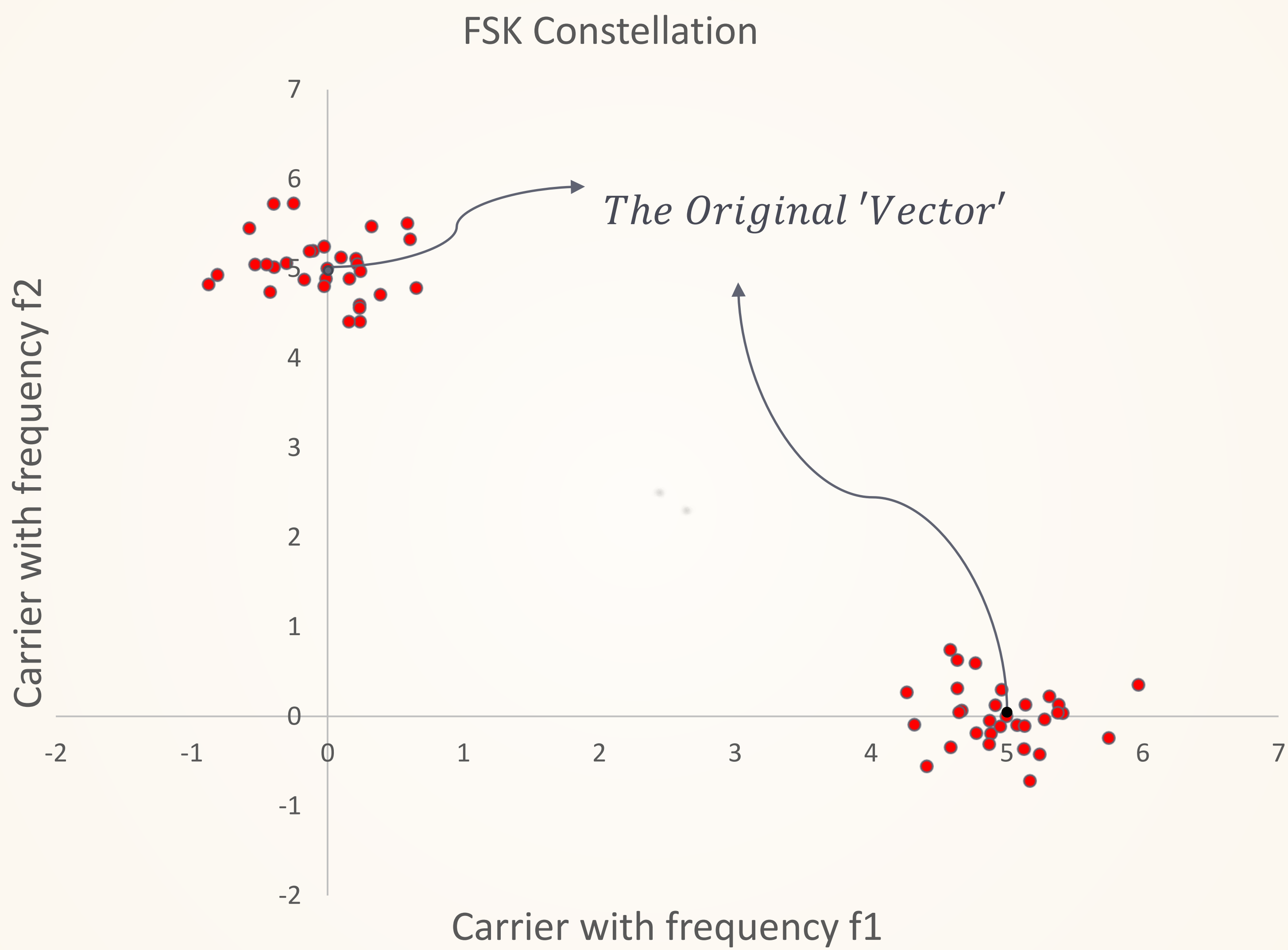
$$[2\ 6\ 4]$$

$$\begin{bmatrix} 6 \\ 2 \\ 4 \end{bmatrix}$$




2-D Vectors as Points
3.5
3
2.5
2
1.5
1
0.5
0
Y Axis
2, 3
1, 2
1, 1
0
0.5
1
1.5
2
2.5
X Axis


FSK Constellation
6
5
4
3
2
1
0
0, 5
5, 0
0
1
2
3
4
5
6
Carrier with frequency f2
Carrier with frequency f1


FSK Constellation
The Original 'Vector'
Carrier with frequency f2
Carrier with frequency f1
7
6
5
4
3
2
1
0
-1
-2
-2
-1
0
1
2
3
4
5
6
7

What is Distance?

Between vectors x and y

- *Euclidean Distance* $$\sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$
- *Manhattan Distance* $$\sum_{i=1}^{n}|x_i - y_i|$$
- *Mean Squared Distance* $$\frac{1}{n}\sum_{i=1}^{n}(x_i - y_i)^2$$

Conditions For a Distance Measure

$For\ any\ Distance\ function$ $\quad d(x, y)$

- $d(x, y) \geq 0$
- $d(x, y) = 0 \Leftrightarrow x = y$
- $d(x, y) = d(y, x)$
- $d(x, z) \leq d(x, y) + d(y, z)$

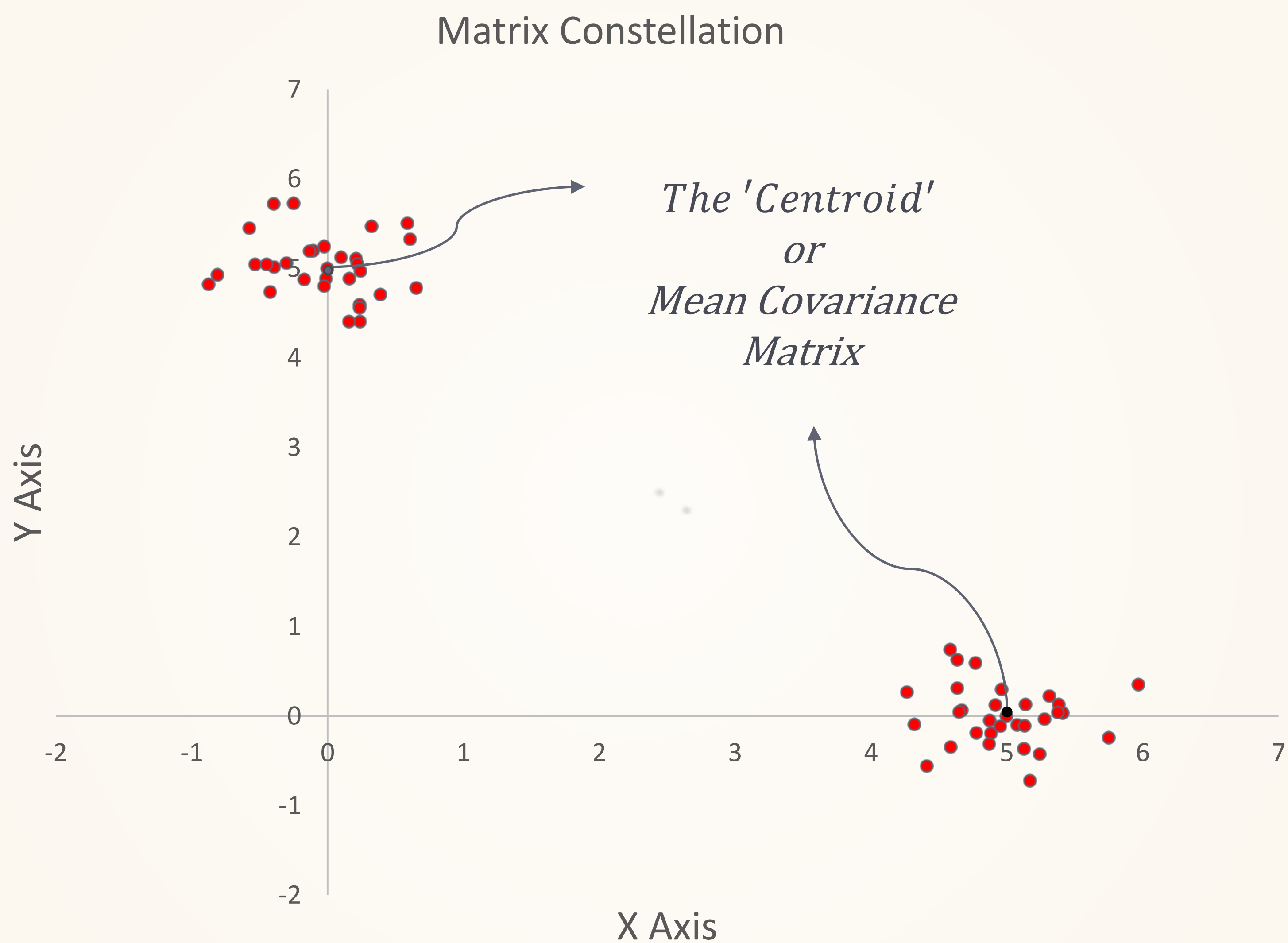
The Riemannian Distance

$$\left\|\ln\left(C_1^{-1}C_2\right)\right\|_F$$

Frobenius Norm of Matrix A is

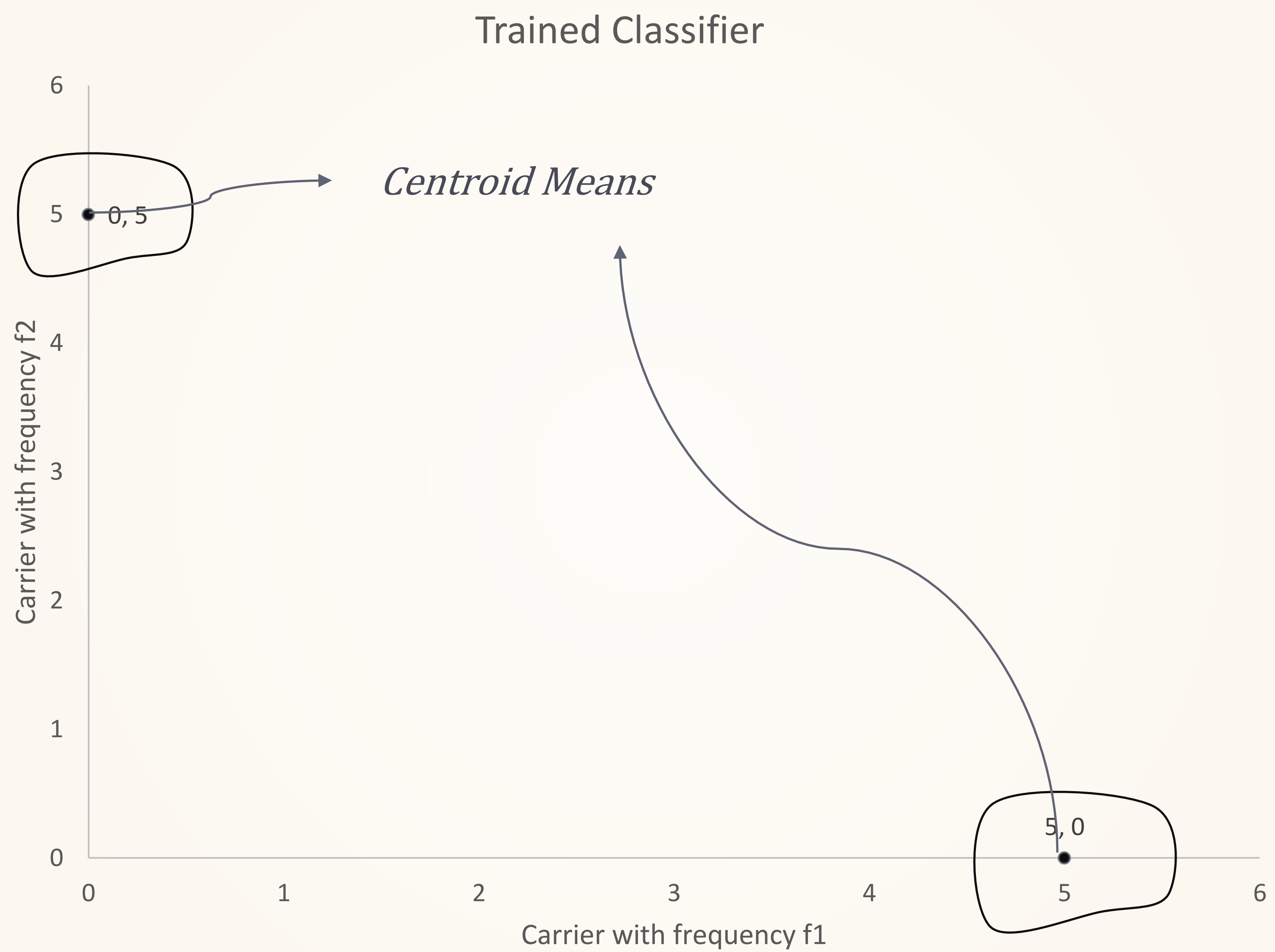
$$\|A\|_F \triangleq \sqrt{\sum_{i=1,j=1}^{m,n} a_{ij}^2}$$

Where a_{ij} *is the* (i,j)*th element of matrix* A


Matrix Constellation
The 'Centroid'
or
Mean Covariance
Matrix
Y Axis
X Axis
7
6
5
4
3
2
1
0
-1
-2
-2
-1
0
1
2
3
4
5
6
7

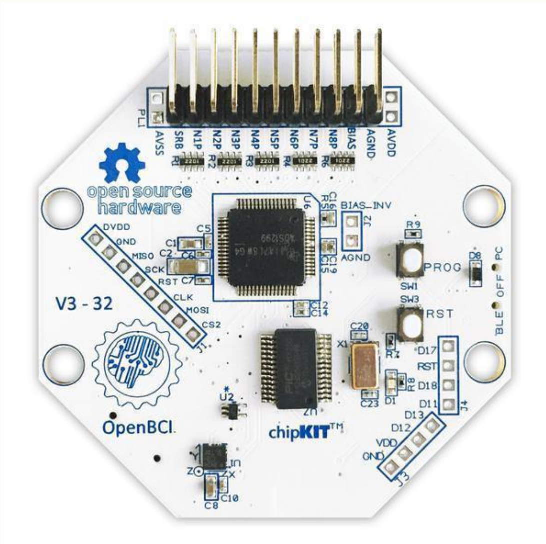
The Point of This All

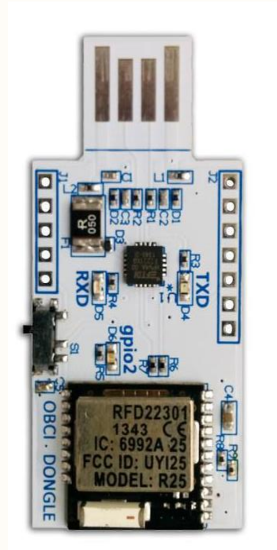
- Each covariance matrix is a point on an $\frac{m(m+1)}{2}$ dimensional riemannian surface
- Compute a lot of 'points' to get a **cluster**
- The 'centroid' will be the 'mean'
- The centroid is computed using riemannian geometry
- Trained classifier knows the **mean** of each frequency class
- **Distance** between new EEG signal and this mean
- Shortest distance is found and the EEG signal is assigned to that cluster
- **That cluster corresponds to a particular flickering frequency**

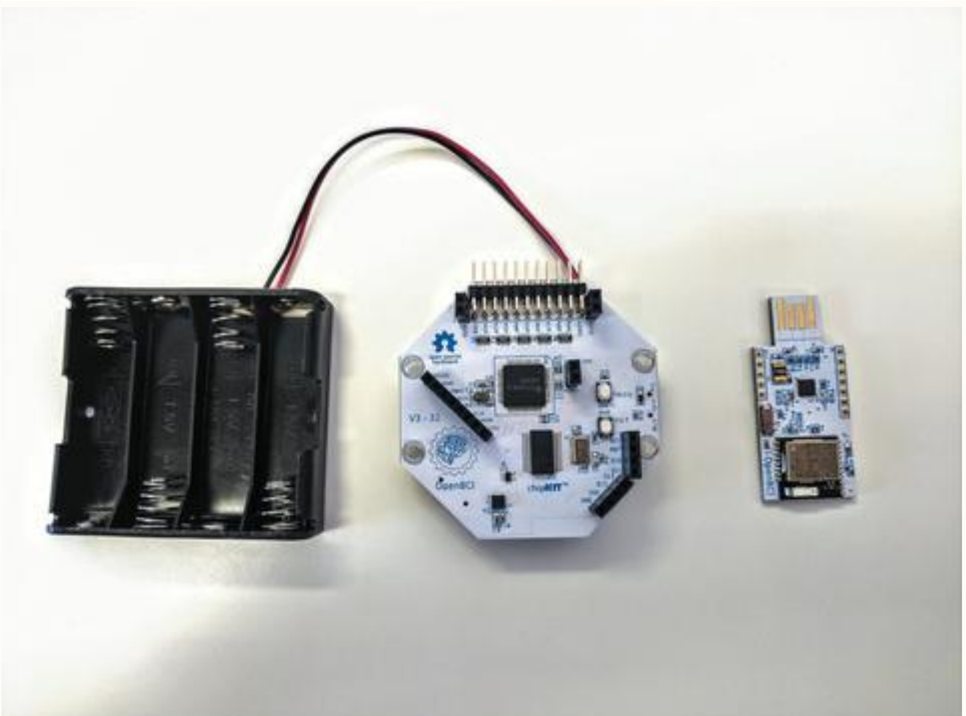

Trained Classifier
Centroid Means
0, 5
5, 0
Carrier with frequency f2
Carrier with frequency f1
0
1
2
3
4
5
6

The Hardware

Cyton Board







The Cyton

Spec Sheet

- Compatible with active and passive electrodes
- 8 differential, high gain, low noise input channels
- Texas Instruments ADS1299 ADC
- PIC32MX250F128B microcontroller
- RFduino Low Power Bluetooth radio
- 24-bit channel data resolution
- Programmable gain: 1, 2, 4, 6, 8, 12, 24
- 3.3V digital operating voltage
- +/-2.5V analog operating voltage
- ~3.3-12V input voltage
- LIS3DH accelerometer
- Micro SD card slot
- 5 GPIO pins, 3 of which can be Analog

The Dongle

Spec Sheet

- RFD22301 radio module from Rfdigital
- FT231X USB-to-serial converter from FTDI
- Can upload code to the OpenBCI board or the dongle
- Fully broken out and pin-compatible RFduino form factor

The Gantt Chart

	Complete	Phase	Q3			Q4			Q1		
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	☐	**SSVEP Classification**									
2	☐	Documentation									
3	☐	SSVEP/Brain study									
4	☐	Understanding the signal acquisition and hardware usage									
5	☐	Obtaining SSVEP datasets									
6	☑	~~Algorithm study~~									
7	☐	Implementing algorithm on a computer									
8	☐	Testing the performance of contrived code									
9	☐	Expanding test set with a different acquisition style									
10	☐	Evaluating performance of code with new dataset									

Thank You