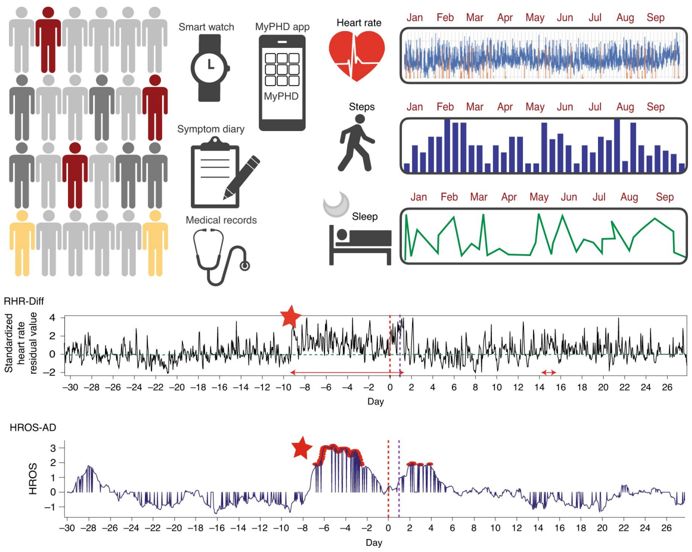
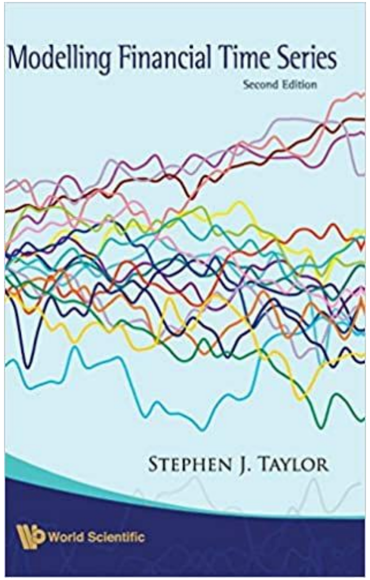
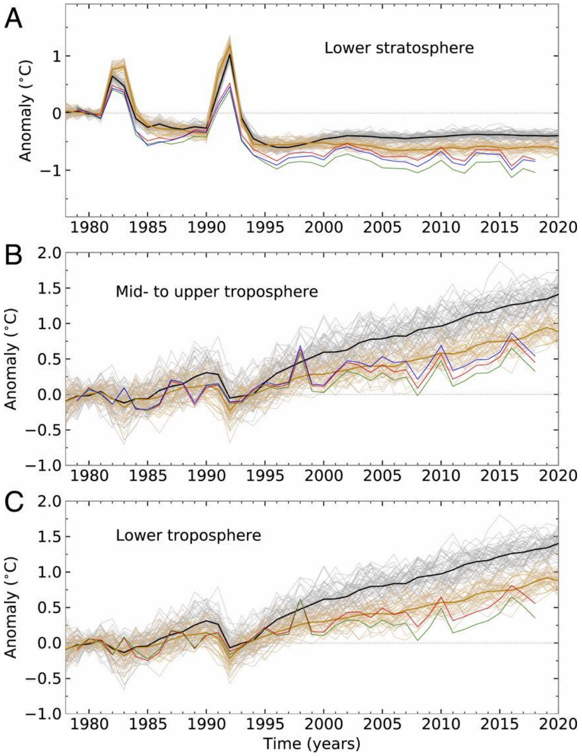
Clustering de Series de Tiempo

Andrés Abeliuk - Hernán Sarmiento



Mishra, T.. *et al.* Pre-symptomatic detection of COVID-19 from smartwatch data. *Nat Biomed Eng* (2020).





Santer, Benjamin D., et al. "Quantifying stochastic uncertainty in detection time of human-caused climate signals." *PNAS* (2019)

Clustering basado en la forma usando el algoritmo K-means

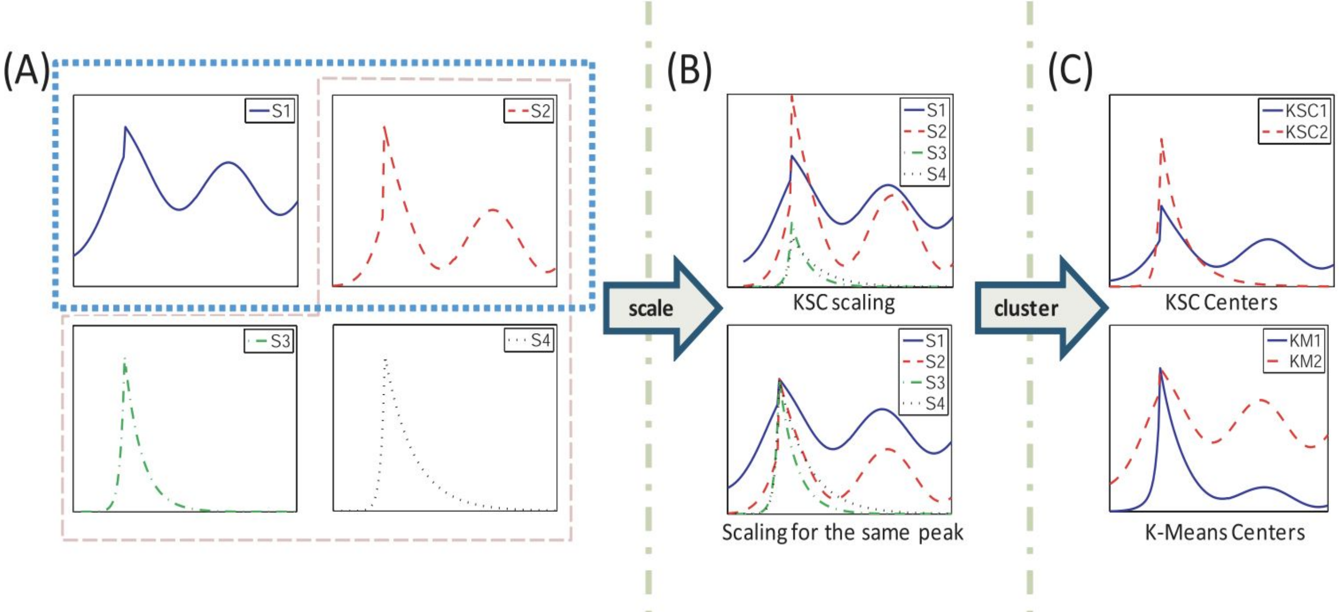


Figure 2: (A) Four time series, S1, . . . , S4. (B) Time series after scaling and alignment. (C) Cluster cetroids. K-Means wrongly puts {S1} in its own cluster and {S2, S3, S4} in the second cluster, while *K-SC* nicely identifies clusters of two vs. single peaked time series.

Yang, Jaewon, and Jure Leskovec. "Patterns of temporal variation in online media." *ACM international conference on Web search and data mining*. 2011

Medida de distancia

$$\hat{d}(x, y) = \min_{\alpha, q} \frac{||x - \alpha y_{(q)}||}{||x||}$$

$$F = \sum_{k=1}^{K} \sum_{x_i \in C_k} \hat{d}(x_i, \mu_k)^2.$$

$$\mu_k^* = \arg\min_{\mu} \sum_{x_i \in C_k} \hat{d}(x_i, \mu)^2.$$

Yang, Jaewon, and Jure Leskovec. "Patterns of temporal variation in online media." *ACM international conference on Web search and data mining*. 2011

Cálculo de Centroide

$$\mu_k^* = \arg\min_{\mu} \sum_{x_i \in C_k} \min_{\alpha_i, q_i} \frac{||\alpha_i x_{i(q_i)} - \mu||^2}{||\mu||^2}$$

Finally, substituting $\sum_{x_i \in C_k} (I - \frac{x_i x_i^T}{||x_i||^2})$ by M leads to the following minimization problem:

$$\mu_k^* = \arg\min_{\mu} \frac{\mu^T M \mu}{||\mu||^2}. \qquad (4)$$

Resultado de álgebra lineal: La solución de este problema es el vector propio (eigenvector) u correspondiente al valor propio más pequeño λ de la matriz M

Extensión: Series de tiempo multidimensionales

Algorithm 1 m-kSC Algorithm

Input: $\{\mathcal{X}, K\}$ where $\mathcal{X} \in \mathbb{R}^{N \times D \times M}$ is the tensor containing N multidimensional time series and K is number of clusters.

Output: $\{\mathcal{C}, S\}$ where $\mathcal{C} \in \mathbb{R}^{K \times D \times M}$ is the tensor of cluster centroids and S contains each cluster assignments.

```
Initialize cluster assignments S randomly
while S changes on every iteration do
    for k = 1 : K do
        for d = 1 : D do
            M = Σ_{x_n ∈ S_k} (I − x_n(d,:) x_n(d,:)^T / ||x_n(d,:)||^2)
            C(k, d, :) = Smallest eigenvector of M.
        end for
    end for
    for n = 1 : N do
        k = argmin_{k=1,...,K} dist(c_k, x_n) using Eq. 1
        S(n) = k
    end for
end while
```

$$M = \sum_{\mathbf{x}_n \in S_k} \left(I - \frac{\mathbf{x}_n(d,:)\mathbf{x}_n(d,:)^T}{\|\mathbf{x}_n(d,:)\|^2}\right)$$

$$k = \underset{k=1,\ldots,K}{\operatorname{argmin}}\, dist(\mathbf{c}_k, \mathbf{x}_n)$$

Ozer, M., Sapienza, A., Abeliuk, A., Muric, G., & Ferrara, E. (2020). Discovering patterns of online popularity from time series. *Expert Systems with Applications*.

Patrones temporales de la evolución de los 1.000 repositorios de GitHub más populares.

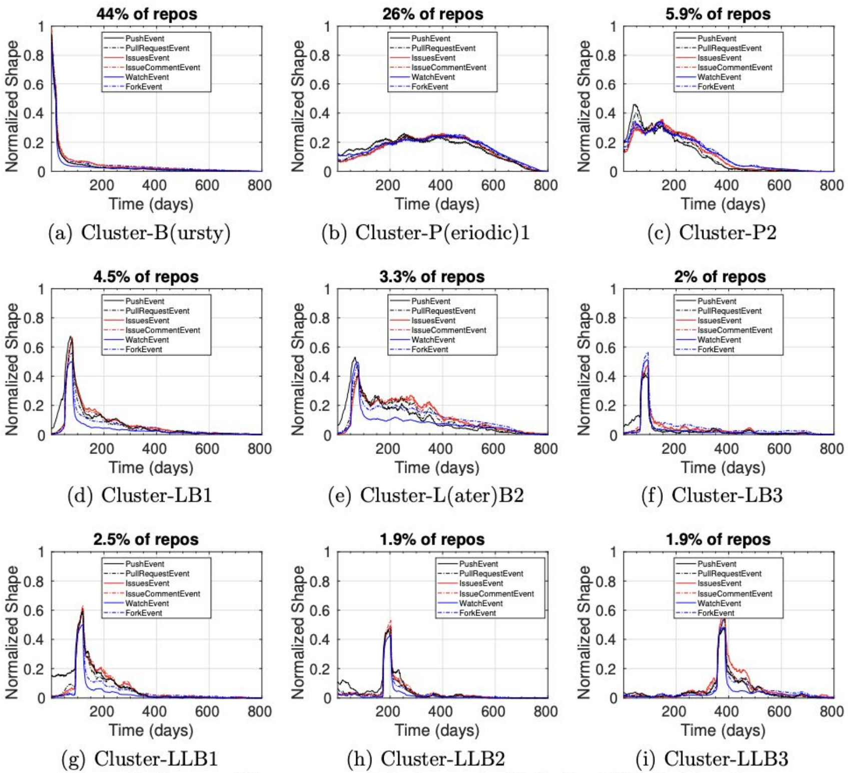


Figure 3: Shapes of the uncovered cluster centroids in the GitHub dataset.

[Ozer, M., Sapienza, A., Abeliuk, A., Muric, G., & Ferrara, E. (2020). Discovering patterns of online popularity from time series. *Expert Systems with Applications*.]

Patrones de popularidad en Twitter

Análisis de la línea de tiempo de los top mil hashtags más populares de Twitter.

Datos desde el 14 de febrero hasta 6 de marzo 2018, relacionado con el tiroteo en la escuela de Parkland.

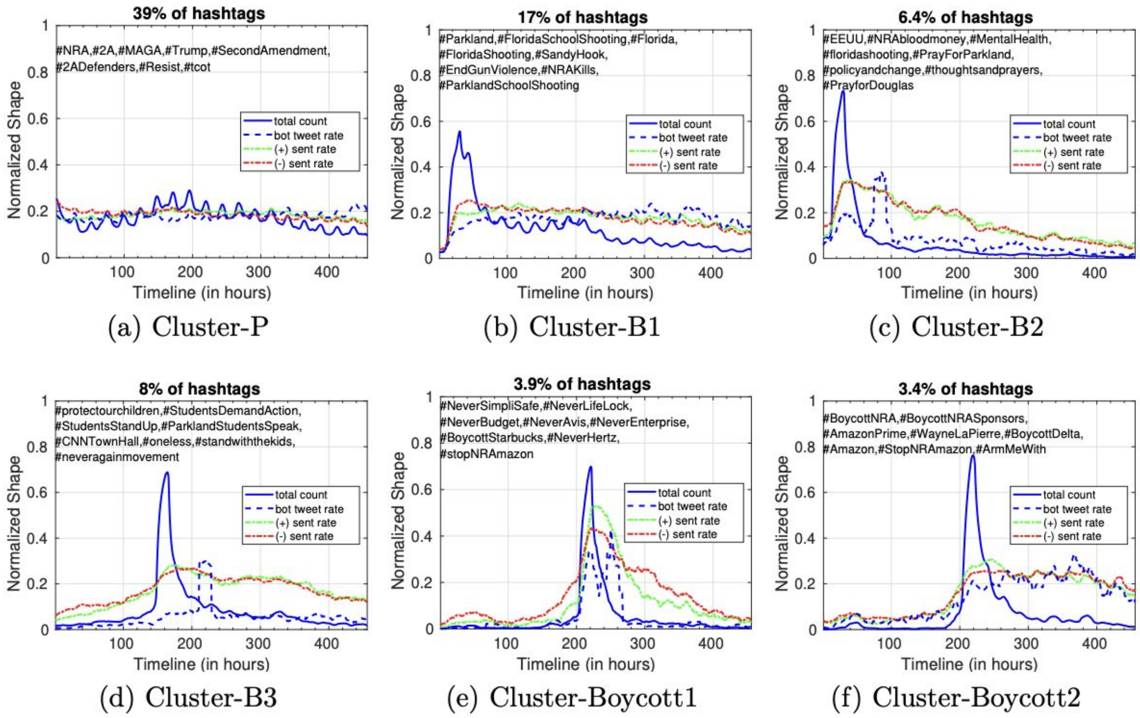


Figure 7: Shape of the uncovered clusters of Twitter

[Ozer, M., Sapienza, A., Abeliuk, A., Muric, G., & Ferrara, E. (2020). Discovering patterns of online popularity from time series. *Expert Systems with Applications*.]