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Seasonality clustering and trend analysis of meteorological data using hybrid approach

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Abstract: Climate change is having a profound impact on weather patterns around the world, leading to shifts in seasonal weather patterns. These changes are affecting everything from the timing of plant growth to the frequency and intensity of natural disasters like hurricanes and wildfires. We conducted a comprehensive review of existing literature on shifts in seasonality focusing on changes in plant phenology, animal migration, and other ecological indicators. We found that many ecosystems are experiencing earlier spring start, later fall end, and longer vegetation seasons, with some regions also experiencing more extreme weather events such as hurricanes, droughts, and floods. These changes are having significant impacts on biodiversity, food production, as well as human health and lives. Seasonal clustering is a useful tool for identifying patterns in seasonal shifts, particularly in the context of climate change.

This research aims to demonstrate a method for analyzing and visualizing seasonal clustering patterns using a combination of unsupervised machine learning algorithms like k-means, k-medoids and agglomerative hierarchical clustering and phenological analysis. Dynamic time wrapping technique is used to measure similarity between meteorological time series. Data pre-processing techniques (e.g., linear interpolation, z-score normalization, and principal component analysis) are employed to remove noise, standardize the temporal scale, and reduce the features for similarity modeling.

Using the past 69 years (1953–2022) of meteorological data recorded in Toronto, Ontario, Canada, we observe patterns of seasonality clustering over time and explore the relationship between climate variables and seasonal shifts. Our goal is to analyze these seasonal shifts by clustering meteorological data and grouping these data points based on similarity in their meteorological features. The cluster results are examined using various metrices, including Dunn index, silhouette scores and cluster stability measures.

Our research also examines the trends observed in meteorological features over the past 69 years using statistical Mann-Kendall trend test to identify signs of climate change. We further investigate the break points in the trends, where a year or several years can be identified dividing the whole period of observations into statistically significant and distinct periods using the Welch t-test. The study in trends of individual meteorological features allows us to identify the features with the most prominent contribution towards the seasonal shifts. By improving our understanding of seasonal clustering patterns and trends observed in historical meteorological data, the outputs of this research can inform policy- and decision-makers on more effective climate adaption and mitigation strategies helping to reduce the impact of climate change on both human society and environmental systems.

Keywords: *Seasonality shift, principal component analysis, clustering algorithm, trend analysis, ecosystem*