DEMO ARXIV TEMPLATE

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ABSTRACT

- Indices, useful, quantify severity, early monitoring,
- A huge number of indices have been proposed by domain experts, however, a large majority of them are not being adopted, reused, and compared in research or in practice.
- One of the reasons for this is the plenty of indices are quite complex and there is no obvious easy-to-use implementation to apply them to user's data.
- The paper describes a general pipeline framework to construct indices from spatio-temporal data,
- This allows all the indices to be constructed through a uniform data pipeline and different indices to vary on the details of each step in the data pipeline and their orders.
- The pipeline proposed aim to smooth the workflow of index construction through breaking down the complicated steps proposed by various indices into small building blocks shared by most of the indices.
- The framework will be demonstrated with drought indices as examples, but appliable in general to environmental indices constructed from multivariate spatio-temporal data

***K*eywords** spatio-temporal data • indices • data pipeline

- indices, why do we need them, decision making
- define what is an index, what is not even if they are called index
- only very brief on indices in the introduction
- potential audience + what do you think they should learn from this work.

1 Introduction

Why index is useful, why people care about indices

- decision making: need to consider multi-facet for allocating resources, [. . .]
- to quantify concept without direct measure. 1) almost impossible to include all the items in the market, indices created from a basket of representative items are useful to characterise the market condition; 2) the concept of interest can't be directly measured, i.e. livability, human developement etc

Integrate multiple information to produce a single number summary (across time).

Define what is an index, what is not

Indices quantify a concept of interest that is hard to measure using [. . .]. over time. In finance and economic, the behavior of stock market, indices like Dow Jones Industrial Average, S&P 500, and Nasdaq Composite uses a representative set of companies. Natural hazard are also indices difficult to define because . . . . Various drought, flood indices have been developed to characterise the severity and monitor from the perspective of meteorology, agricultural, hydrology, and also socio-economy. Examples of indices are ubiquitous: economic indices for quantifying productibility (GDP?), inflation (CPI), [. . .]; Social development indices like Human Development Index and Global Liveability Index; diversity indices to characterise the richness, evenness and dominance in ecology

Despite many measurements are called indices, they are actually not indices, but metrics. A direct rate or transformation on a measured variable: birth & death rate computes the total number of new-borns and death per 1000 people. Many remote sensing measures are not indices, i.e. Normalized Difference Vegetation Index (NDVI), despite being named as an index, is a mere statistical transformation: the difference of near-infrared (NIR) and red visible channel over its sum.

fire index

- need think through:
  - is cash rate/ interest rate indices? employment rate? eocnomic indices?

What is the problem with current workflow on index construction

- most indices are presented as calculated numerical or categorical values without open source code accompanied.
- This causes the problem that if analysts are not agreed with a certain step in the index construction, there is no room for experiment with other possibility.

There has not yet been a standardised workflow on index construction. For simple indices, users may be able to work out the calculation from the equations or workflow provided, while for more complicated construction, software is not even available for open-source consumption. Even when the software implementation is available, most indices are computed through a single index command, for example, the package `SPEI` provides two drought indices: SPI and SPEI through function `spi()` and `spei()`. This software design focuses on the name of the index and includes all the steps in a single index function. With this design, there is little room for modification. For example, fit a new distribution that is not provided in the initial code. Also, when scaled to a large number of indices, it increases the cognitive load of remembering hundreds of index names. A better approach is to modularise these steps and construct a pipeline for users to build indices through choosing different building blocks from each module. With this design, users focus on the operations involved in the index construction. If an operation from another index is useful, users can borrow it to modify an existing index.

who would benefit from this paper

The article contributes a pipeline framework to construct general indices.

- domain scientists who propose new indices and directly use indices in analysis. [use multiple indices to compare]
- decision makers, towards understand the
- statisticians, so as to [draw focus/ advocate] on statistical workflow and software design.

The rest of the paper is structured as follows: the concept of data pipeline in R is reviewed in Section 2. Section 3 presents the data pipeline for index construction. Section 4 explains how to include a new building block in each pipeline module. Examples are given in Section 5 to demonstrate the index construction with the pipeline built.

2 Data pipeline in R

2.1 Tidy data

Before the concept of tidy data (Wickham 2014), tabular data arrive at data analysts in all different ways. Different analysts would write customised scripts for analysing the specific data. These scripts can be extended to other data analysed by the same people or group but this is not generalizable directly to another dataset. When the tidy data concept comes, variables and values are arranged so that 1) Each variable forms a column, 2) Each observation forms a row, and; 3) Each type of observational unit forms a table. With this specific layout, wrangling on tabular data can be standardised into a grammar of data manipulation in `dplyr` (Wickham et al. 2022).

A similar issue happens with index construction where researchers construct their own indices in their own ways and there has not yet been a tidy principle on index construction. Also, this tidy principle on index construction is more complex than those in tidy data and the `dplyr` package. It has to encompass the workflow of transformation from the raw data towards the final index series.

2.2 Data pipeline

Constructing a pipeline that divides a complex procedure into steps that can be concatenated has been adopted widely in the R community.

The data pipeline in interactive graphics is a set of steps that transform the raw data to the plots displayed on the screen. The initial pipeline proposed by Buja et al. (1988) involves the following steps: non-linear transformation, variables standardization, randomization, projection engine, and viewporting. The initial pipeline proposed by Buja et al. (1988) involves the following steps: non-linear transformation, variables standardization, randomization, projection engine, and viewporting. Another example in the early work of pipeline by Sutherland et al. (2000) describes a three-step pipeline: variable standardization, dimension reduction, and scaling data into the viewing window. This pipeline also includes the transformation on spatial and temporal variables, i.e. computing time lag on temporal variables. This pipeline also includes the transformation on spatial and temporal variables, i.e. computing time lag on temporal variables. Wickham et al. (2009) argues that whether made explicit or not, pipeline has to be presented in every graphics program and breaking down graphic rendering into steps is also beneficial for understand the implementation and compare between different graphic systems.

The data pipeline concept is further enhanced by the pipe operator (`%>%`) in R where a set of operations, or steps, can be chained together to form a set of instructions.

A more recent data pipeline is tidymodels (Kuhn and Wickham 2020), a set of packages for machine learning models following the tidyverse principles (Wickham et al. 2019). Steps: Exploratory data analysis (EDA), feature engineering, model tuning and selection, and model evaluation.

3 A pipeline for building statistical indices

The construction of natural hazard indices also follows a set of steps, which is usually illustrated using a flowchart in the paper. However, every researcher follows a certain design philosophy and steps taken in the index constructed by different researchers are not aligned. This discourages experiment with multiple indices. Initiate a new workflow when computing a new index.

The most popular indices (i.e. SPI, SPEI, etc) have existing software implementation (`SPEI`) to be applied to a different set of data.

constructing time series index should also be encapsulated in my framework

reusable

3.1 Raw data

Another section on original data directly downloaded, can have different spatial resolution, temporal granularity, data quality problem. After processing them and align them together they become the "raw data"

The data used to construct the natural hazard index usually have three dimensions, one for location, one for time, and one for multivariate. Mathematically, it can be written as $X_{j,s,t}$, where $j = 1, 2, \cdots, J$ for variable, $s = 1, 2, \cdots, S$ for location, and $t = 1, 2, \cdots, T$ for time.

The location s can refer to vector points or areas characterised by longitude-latitude coordinates, or raster cells obtained from satellite images.

The time dimension t can be daily, weekly, biweekly (14-16 days), monthly, or even quarterly

Variables

This multidimensional array structure is commonly used in geospatial analysis

Given the variety of data sources at different spatial resolution and temporal granularity, the raw data may first come in multiple pieces. Sometimes, even a considerable amount of work is needed to align the spatial and temporal extent of multivariate data.

A notation for different variables have different spatial and temporal granularity X_{j_1,s_1,t_1} ???

3.2 Spatial aggregation

mostly happen with raster data

3.3 Scaling

A specific transformation on the scale of the data

z-score standardising, min-max standardisation into [0, 1] or [0, 100], percentage change on the baseline close to variable transformation step

3.4 Variable transformation

Restrict it to single variable, square root, log etc could be linearly, also non-linear

GAM, can you do additive model pairwise/ three-way

3.5 Temporal processing

3.6 Dimension reduction

sometimes called feature extraction in the machine learning community With drought indices, the extraction of meaningful variables from the original data is usually supported by the water balance model, for example, in SPEI, the step that create d out of precipitation and potential evapotranspiration (PET) has theoretical backup from [see paper.]

Also include weighting

3.7 Normalising

The purpose of normalising is for cross-comparison. This step can get criticism from analysts for ...

specifically for converting from a fitted distribution to normal score via reverse CDF function, non-parametric formula, or empirical approximation, a common step in many index: SPI, SSI, Z score. The purpose of normalising is to convert the index into a standardised series after all the steps for the ease of comparison.

3.8 Benchmarking

3.9 Simplification

Discretise the continuous index into a few labelled categories. For communicating the severity of natural hazard to general public.

uniform workflow to work with index construction.

- illustration
- math notation
- benefit of the pipeline approach
  - index diagnostic
  - uncertainty

4 Incorporating new buliding blocks into the pipeline

5 Examples

5.1 Constructing Standardised Precipitation Index (SPI)

- a basic workflow and congruence with results in the `SPEI` pkg
- allow multiple distribution fit
- allow bootstrap uncertainty

5.2 Calculating SPEI with raster data

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