

User Study

1. Introduction

This study aims to evaluate our visual analytic tool, Time Series BarCode (TSBC), for understanding the feature inside the time series data. At the core of our design is the usage of persistent homology and the operations that adjust persistence and combine barcodes. This introduction will cover the detailed usage of TSBC's visual interface and interaction.

1.1 Persistence

Persistence is a concept that underlie the theory of persistent homology. It shows how long may a feature survive during the change of filtration threshold. In time series (1D scalar function), the term "feature" refers to the extrema (i.e., maxima and minima). Given the maxima and minima, a time series can be easily divided into many small monotonic segments. The persistence is the L_∞ distance between the birth point and the death point. Intuitively, we may consider a maxima and its neighborhood as a "hill" and a minima and its neighborhood as a "valley". The boundary of a "hill" is the two "valleys" surrounding it, and the boundary of a "valley" is the two "hills" bounding it. The persistence describe how much effort will be needed to move a "hill" (maxima) or a "valley" (minima) from the terrain (time series), i.e., how tall a "hill" is or how shallow a "valley" is. Traditionally, the persistent barcode and persistent diagram are used to describe the picture given by persistent homology. In the persistent barcode, each vertical bar represents the survival period of one feature. The bars are usually in the ascending order of birth time. In the persistent diagram, each point represent one feature, where its x-coordinate represents its birth time and its y-coordinate represents its death time.

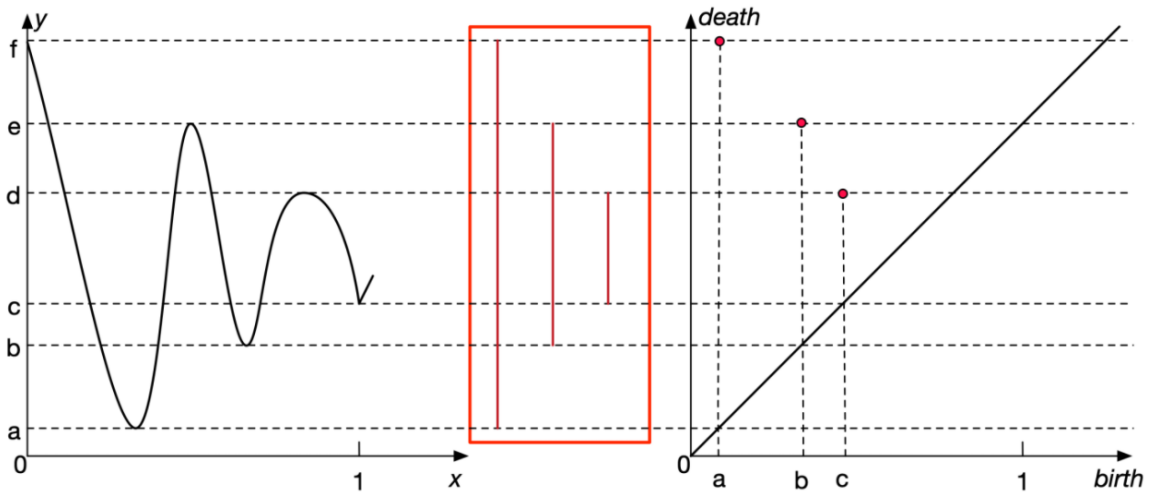


Figure 1. Line chart of time series data and its persistent diagram.

1.2 Visual Encoding

The line graph, persistent barcode, and persistent diagram may contain an overwhelming amount of details when the time series becomes complicated. We aims to provide a concise picture with an adjustable simplification level based on persistence. The features with persistence value small than the user-specified threshold will be remove, and the remaining ones will be visually encoded by a

barcode-based representation. In this survey, we would like to you to rate which visual mapping between the encoding channels and feature attributes is more effective or intuitive to you.

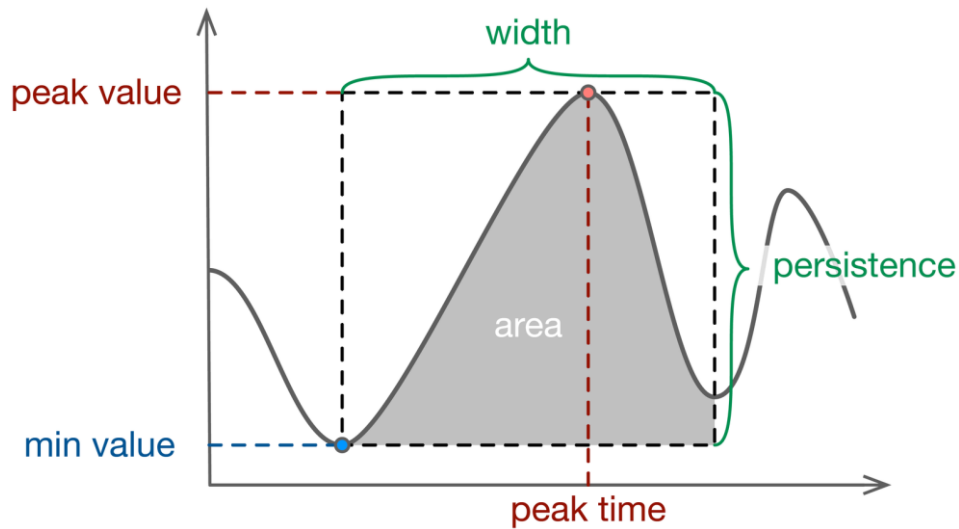


Figure 2. The attributes associated with a feature ("hill").

1.2.1 Attributes

The attributes associated with a feature ("hill") is illustrated in Figure 2, including:

- Width: the time interval between two minima.
- Peak value: the value of the maxima on top of the hill.
- Peak time: the time corresponding to the maxima.
- Min value: the minima at the bottom of the neighboring valley.
- Persistence: the L_∞ distance between the birth point and the death point of the hill.
- Area ratio: the ratio of the area below the line and the total area of the bounding box.

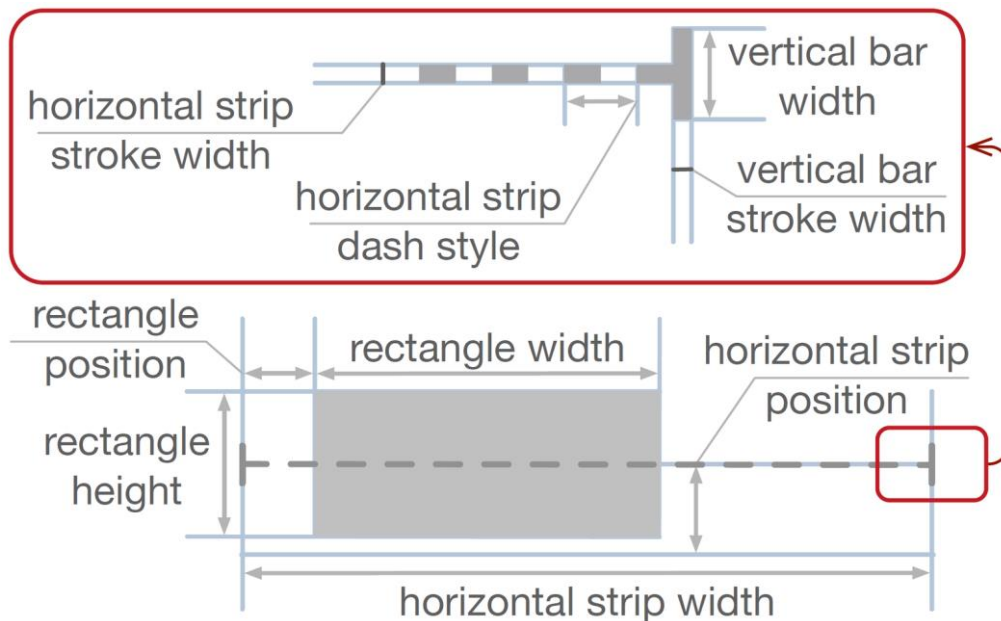


Figure 3. The visual encoding channels provided by a segment in the barcode.

1.2.2 Visual encoding channel

Each segment in the barcode provides three visual elements: a rectangle, a vertical separation bar, and a horizontal dashed strip, as shown in Figure 3. Each element provides a series of channels for visual encoding:

- The rectangle:
 - width, height: the width and height of the rectangle.
 - vertical position: the vertical difference between the center point of the rectangle and the horizontal strip.
- The vertical separation bar:
 - height: the height of the bar.
 - stroke width: the thickness of the bar.
- The horizontal dashed strip:
 - span: the horizontal span of the strip.
 - vertical position: the y-coordinate of the strip starting from the bottom of the barcode.
 - stroke width: the thickness of the strip.
 - dash style: the density of the dashes.

2.View

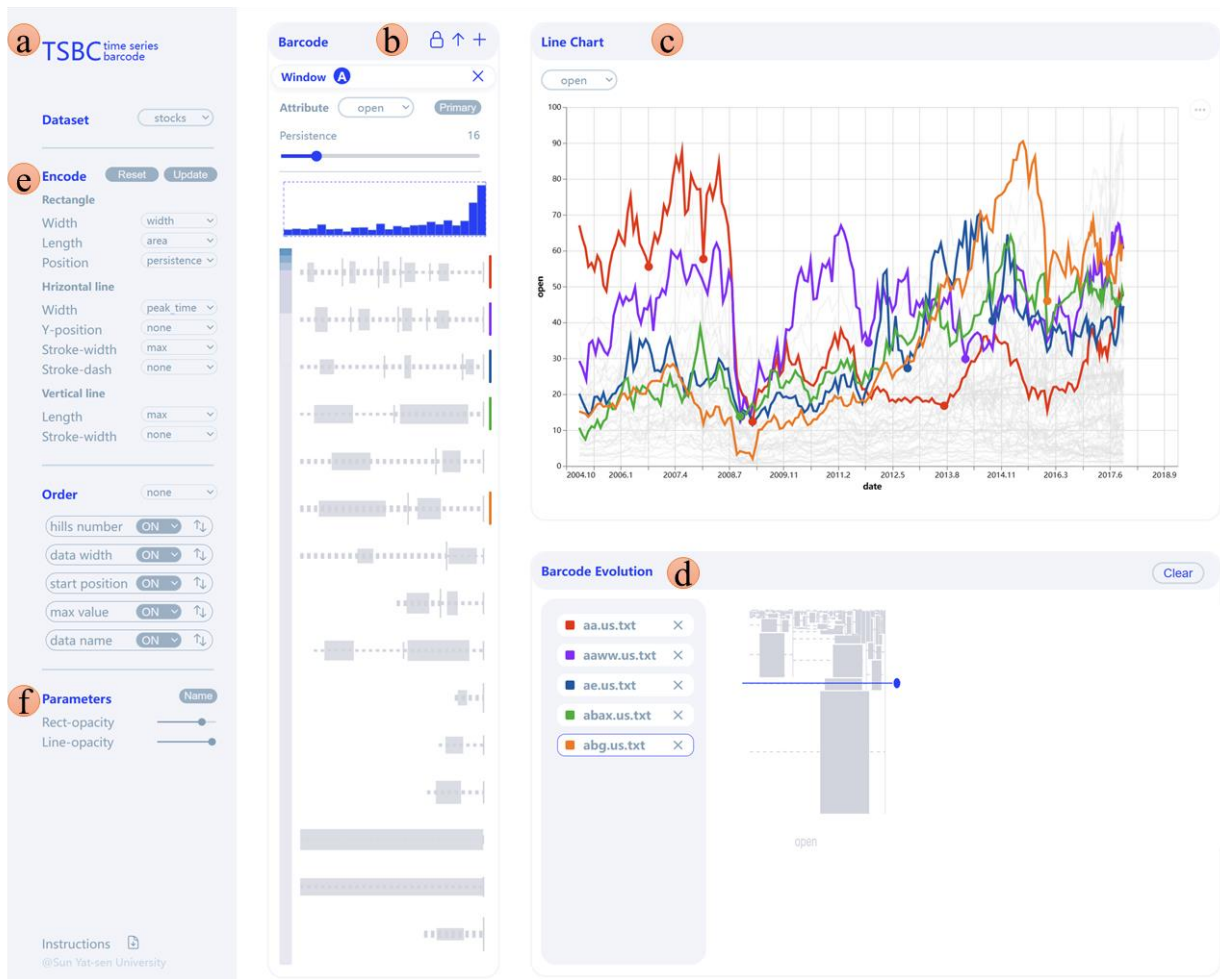


Figure 4. The interface of TSBC.

Our system consists of six views, and each view and their function are introduced as follow.

(a) Dataset View: At this view, you may upload dataset if need. Some example datasets are also provided. While finishing loading, the corresponding line chart and barcodes would be rendering at their module.

(b) Barcode View: This view show the barcodes for different attributes and persistence values. The color of scroll bar next to the barcode show the segment number of the corresponding barcode. The deeper color, the more the segments. You may show the name of data by the "name" button. At most three barcode windows are allowed. You may add the windows by "+" icon on the right-top, close the windows by "x" icon, and change the attribute by the select box. Two way to adjust persistence are introduced later.

(c) Line Chart View: This view show the linechart of the dataset. The selected data will be highlight. And the point divided barcode into different segments will be highlight together. You may change the attribute by the select box on the left-top.

(d) Barcode Evolution View: All the selected data will be shown in this view. You may click the name of data show its tree of barcode. The barcode tree looks like merge tree., which records the birth

point and death point and then links them correspondingly. But barcode tree merge them with persistence. Each horizontal position of barcode tree show a persistence value, and the persistence continues to increase from top to bottom. While the persistence value is too big to exceed the persistence of the hill. We merge it with the segment nearby. The barcode tree show the evolution of barcode from lower persistence to higher.

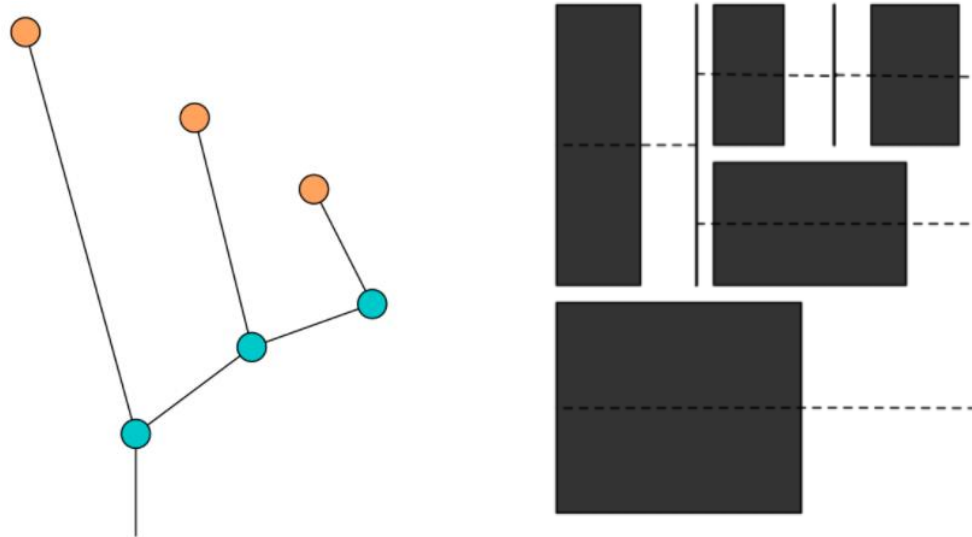


Figure 5. merge tree and barcode tree

(e) Encoding Channel View: At this view, you may put different information into different channels randomly. And then the shape of barcode in Barcode View will be change.

(f) Parameters View: At this view, you may adjust some parameters of the barcode. The process bar called "line opacity" and "rect opacity" decide the opacity of barcode. The switch called "global time" and "global value" decide the information of barcode whether depend on the global data or not.

3.Interaction

1. Persistence adjustment

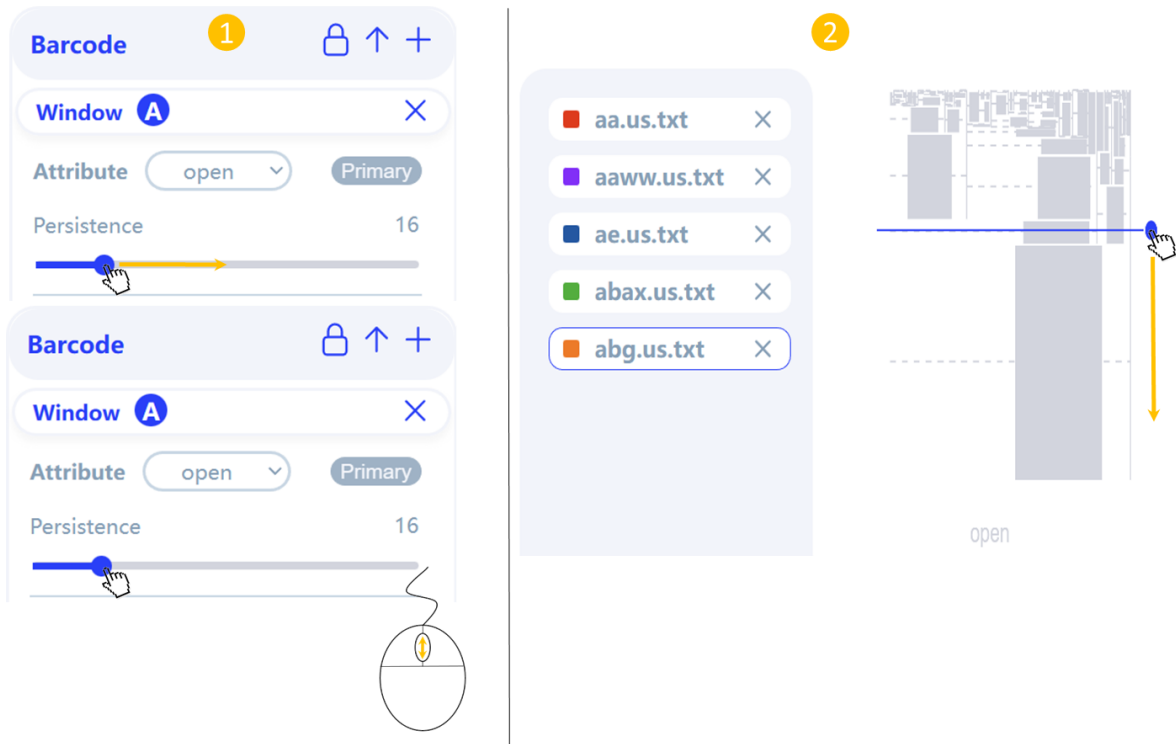


Figure 5. Two way to adjust persistence

There are two ways to adjust persistence value. For the first way, you may drag the progress bar for coarse adjustment and scroll the mouse for fine adjustment at the upper part of **Barcode View**. For the second way, you may move the line with icon of **Barcode Evolution View** to adjust the persistence value of corresponding barcode windows.

2. Time series selection

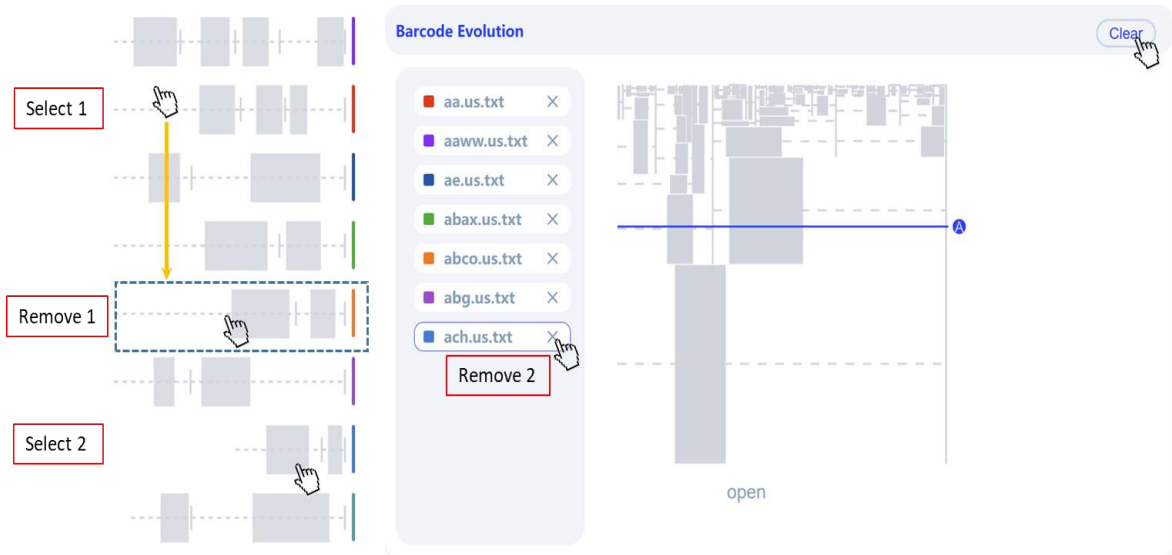


Figure 6. The ways to select or remove time series data

You may brush barcodes vertically to select a great number of data (Select 1). Or you may click one barcode to select one data (Select 2). On the contrary, you may click the selected one to remove the barcodes from selection (Remove 1). Besides, you may remove the selected data by the "x" icon next to its name at the **Barcode Evolution View** (Remove 2). Further more, you may clear all the selected data by "clear" button on its left-top (Clear). You may click the button "top selected" to move selected barcode on top of each column in barcode view.

3. Time span selection

To view data for a fixed time zone, you may select the area of time span. And there are three ways to adjust it.

- (1) You may drag the time box to move the position of time box.
- (2) You may move the bound of selected time box to change the boundary of time span.
- (3) You may brushing outside time box to create a new time box and cover the older.

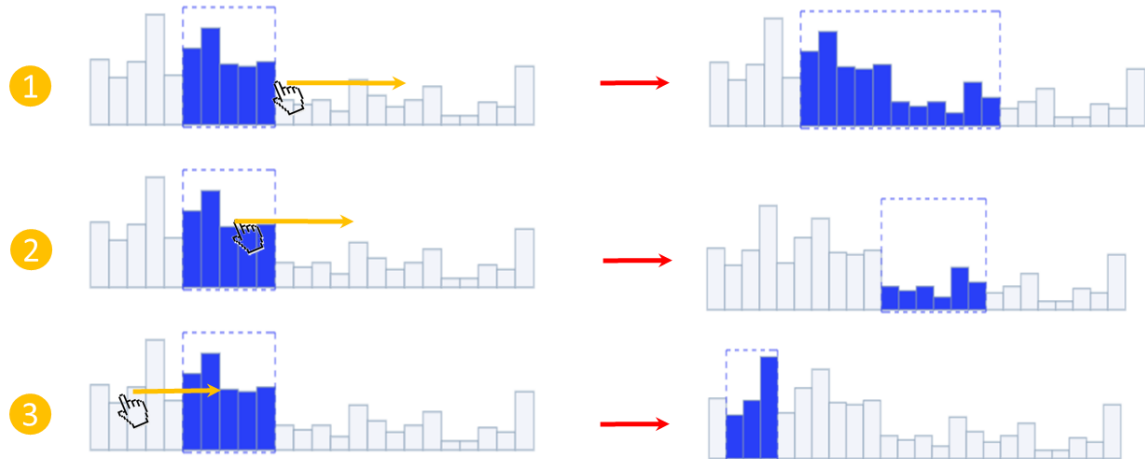


Figure 7. Three ways to select time span

4. Barcode segment query

You may brush code horizontally to query segments of a barcode (as highlighted in red in Figure 8), and the similar segments in other barcodes will be matched (as highlighted in pink in Figure 8). You may click the button "top matching" to move the matched segments onto the top of each column in barcode view also.

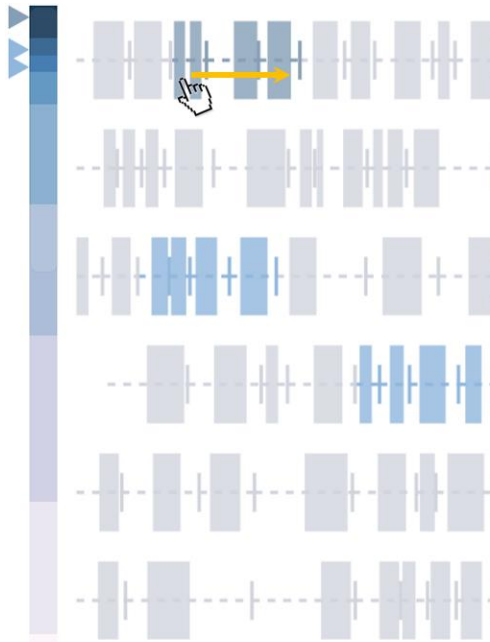


Figure 8. The query of barcode segment

5. Sorting the barcodes

In order to sort the barcode by different priority, you can use the order parameters panel to determine the sort priority. You may switch "on/off" to decide if using the sorting parameters. And you may switch "re" to decide reverse ordering or not. You can determine the sorting priority

by holding down the left mouse button and dragging the sorting parameters. You may select the specified window to sort through the drop-down box.

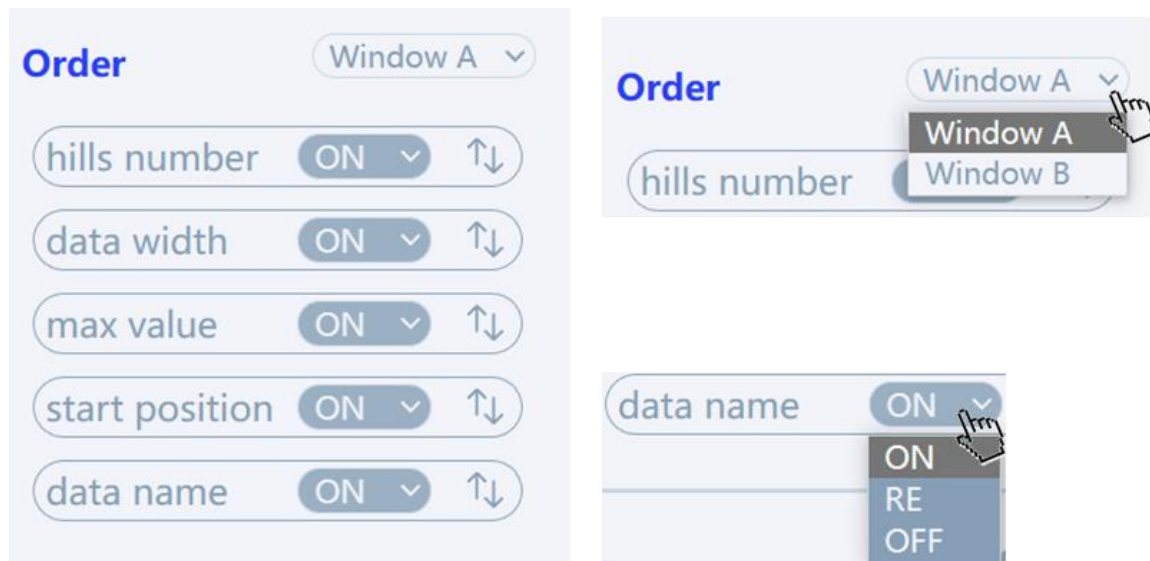


Figure 9. Sorting barcode mode

We provide two sorting modes: independent mode and coupled mode. In independent mode, all "primary" buttons will have an unlocked icon next to them, and all barcode windows will be sorted according to their own sorting priority. You may click the "reorder" button to sort barcodes by default priority. If you want to change the sorting priority, you may open the sorting window and adjust the sorting rules. And Then the barcodes will be sorted according to the new priority.

In coupling mode, there is only one "primary" button with a locked icon next to it. And other barcode windows will be sorted according to the barcode order to which the icon belongs. So that barcodes from the same data will be placed in the same location. You may switch the barcode window used for sorting in coupling mode by clicking the "primary" button without icon, and switch between independent mode and coupling mode by clicking the "primary" button with an icon.