Supplementary Report
Elastic Data Binning for Transient Pattern Analysis in Time-Domain Astrophysics

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1 Introduction

This document is a supplementary report for the "elastic data binning for transient pattern analysis in time-domain astrophysical" publication, that appears in The 38th ACM/SIGAPP Symposium On Applied Computing (**SAC 2023**). Please feel free to contact us if you need any further information.

2 LCs dataset from the optical telescope

Our dataset considered here is comprised of LCs, it came from an optical wide-field video observation system composed of a mosaic Complementary Metal-Oxide Semiconductor (CMOS) camera on the Kiso Schmidt telescope for sky survey [1]. We category from some essential characteristics into four scenarios that happened during the sky survey, which is shown in Fig 1. Every scenario of LCs that we found is described as followed:

- Stable behavior: This period corresponds to near-constant stable data, and it can be noisy.

- Unstable behavior: This can happen suddenly/abruptly in a period. This scenario occurs from cloud turbulence or the brightness of a nearby celestial star.

- Outlier point: This is an outlier point that may become from confusion noise. It may happen in a few instances on the data stream.

- Gradual changing: This period has slowly changed over time, and it may become new normal behavior. It is one kind of pattern in astronomy. However, this is not our objective.

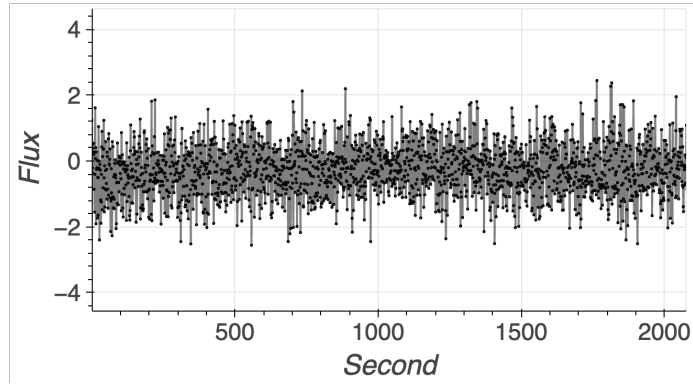### 2.1 Transient pattern injection in LCs

In our experiment, we injected square-wave or triangle-wave transient patterns to evaluate the proposed methods on the dataset. The signature of the square-wave transient pattern suddenly increases and decreases. Conversely, the signature of the triangle-wave transient pattern slowly increases to the peak signal and then decreases to normal. Figures 2 and 3 show comparison between before and after transient pattern injection.

Herein, we defined square-wave and triangle-wave transient patterns with various durations and heights. From the total of 7,616 LCs files, they are composed of one square-wave or triangle-wave transient pattern for each file.
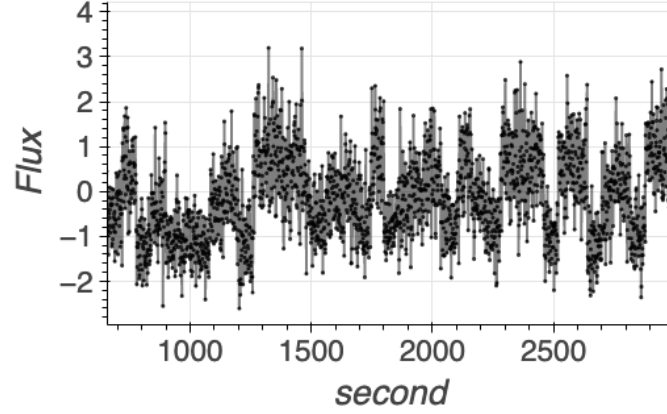
The duration and height of the smallest transient pattern are 60 instances and 1σ, respectively. Conversely, the largest transient pattern is 500 instances for the duration and 3σ for strength height,
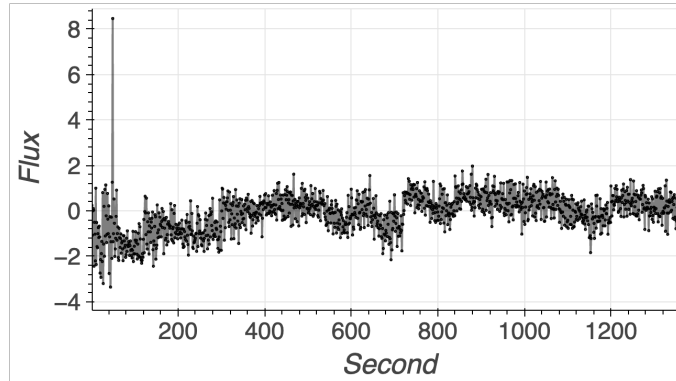
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[1]The dataset provided is from the Tomoe-Gozen project of the Kiso Schmidt telescope. For more detail, visit https://tomoe.mtk.ioa.s.u-tokyo.ac.jp/
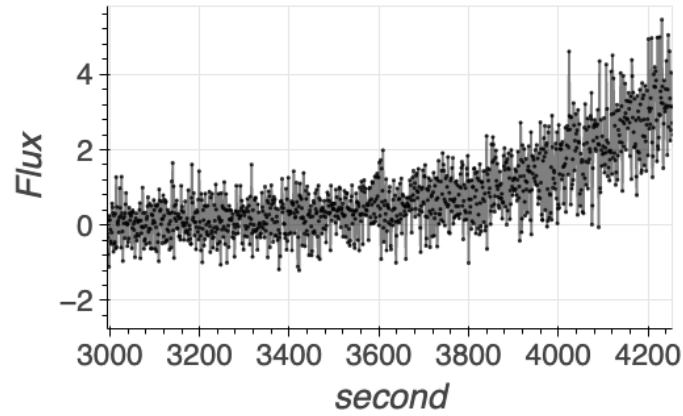
(a) Normal behavior
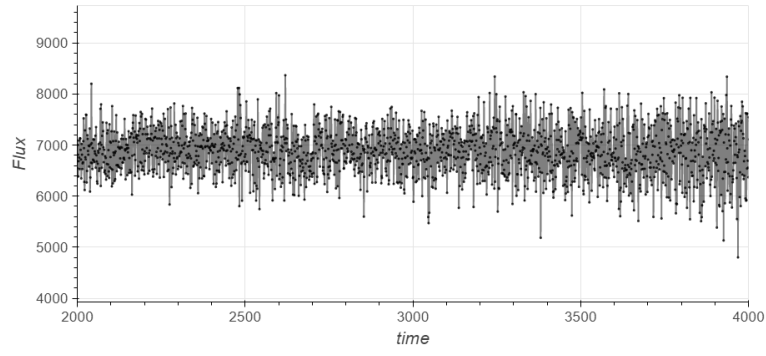

(b) Unstable behavior.
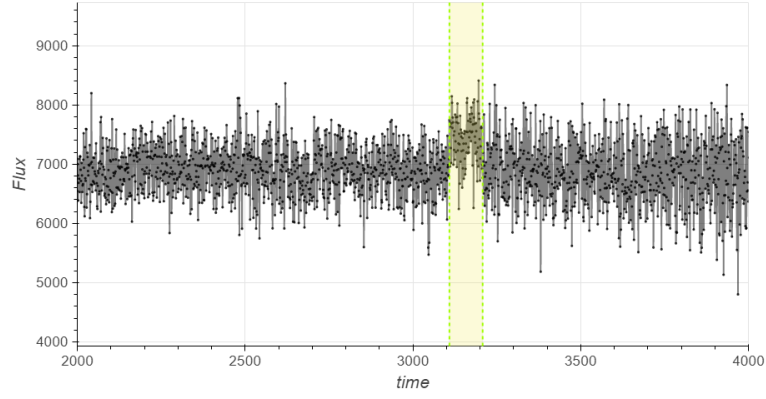

(c) Outlier point

(d) Gradual changing

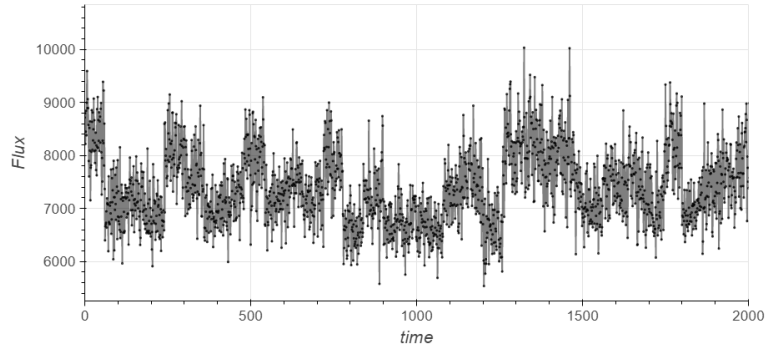Figure 1: Four scenarios in our dataset.

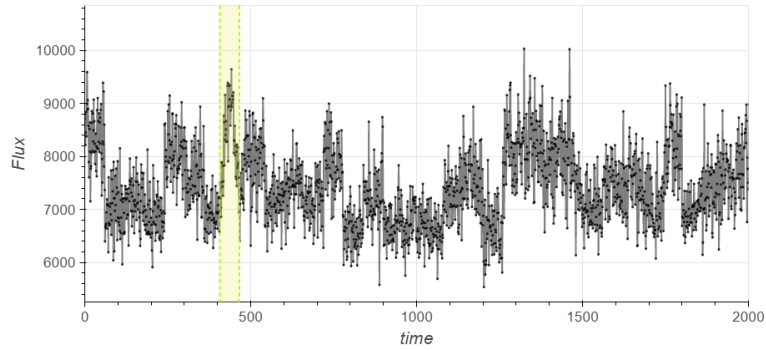(a) Before injection into stable behavior

(b) After injection with square-wave transient pattern with height of 1σ and duration of 100

Figure 2: Comparison between before-after injection

(a) Before injection into unstable behavior

(b) After injection with triangle-wave transient pattern with height of 3σ and duration of 60

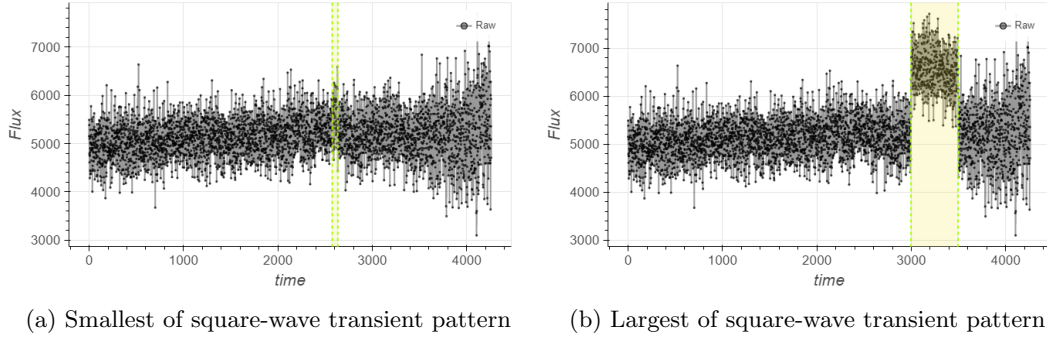Figure 3: Comparison between before-after injection

(a) Smallest of square-wave transient pattern   (b) Largest of square-wave transient pattern

Figure 4: Comparison between the smallest transient pattern and the largest of the square-wave transient pattern.

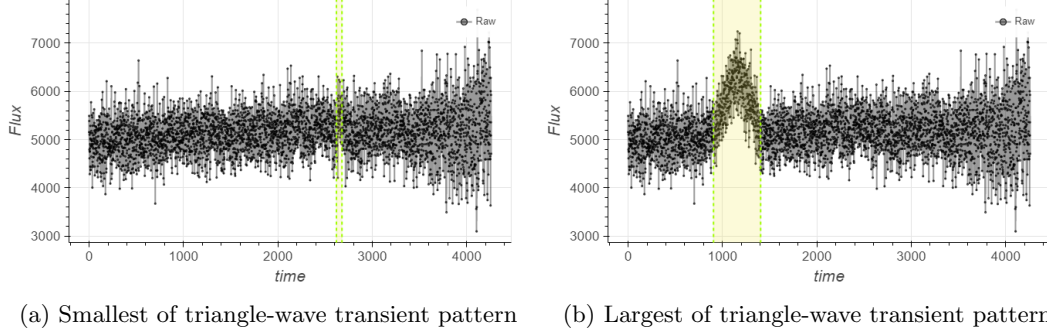(a) Smallest of triangle-wave transient pattern   (b) Largest of triangle-wave transient pattern

Figure 5: Comparison between the smallest transient pattern and the largest triangle-wave transient pattern.

where σ is the standard deviation of the original data for each file. A small sample of the square-wave transient pattern in the LCs is shown in Figure 4a. Figure 4b shows a large square-wave transient pattern. Conversely, in Figure 5a and 5b show a comparison between smallest and largest triangle-wave transient patterns, respectively.

Notably, we knew the starting point and the ending point of all the transient patterns for computing the accuracy rate of our proposed method.

2.2 Special scenario in triangle-wave transient pattern

We found some LCs with triangle-wave transient pattern injection that were similar square-wave transient pattern, as shown Figure 6. They are hard to distinguish triangle-wave transient patterns.

3 Experiments

3.1 Transient pattern capturing quality

This subsection is full results average of bins for representation of and IOU with various height and duration of transient pattern capturing. In Figures 7 - 10, the high intersection of union IOU indicate bin that heavily overlap transient pattern. Conversely, the low number of bins for representation indicates a good segmentation that is used for the transient pattern. The best scenario is a low number of bins for representation with a high IOU.

Notably, fixed bin size of $W = 20$ and $W = 71$ correspond to the transient durations of 200 and 60, respectively. If bin size is equal to transient duration, the value of IOU is increased.

3.2 Representation quality

This subsection presents the Euclidean distance for the representations with various heights of the transient patterns, as shown in Figuers 11 - 13. Note that we set two thresholds; the dashed line and dotted line refer to Euclidean distance of Mean- and Linear-EBinning with w of 20, as shown in Figures 12 and 13
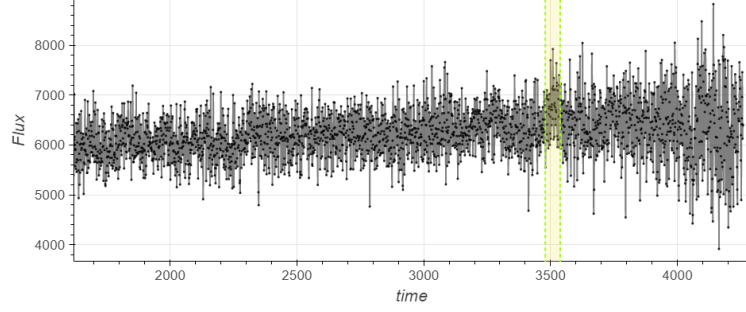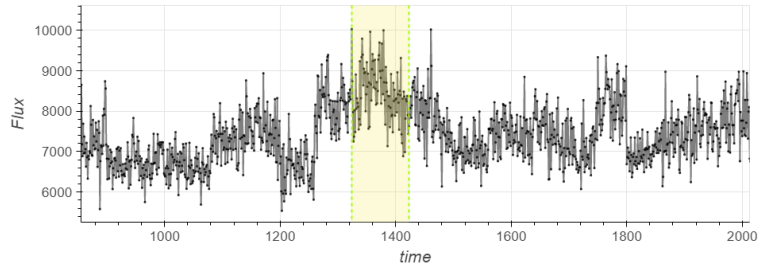
(a) Sample of triangle-wave transient pattern with 1σ and 60 duration
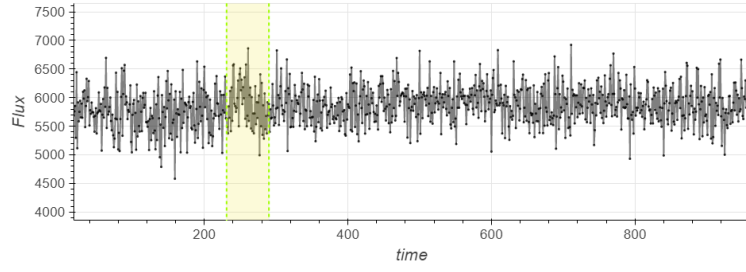
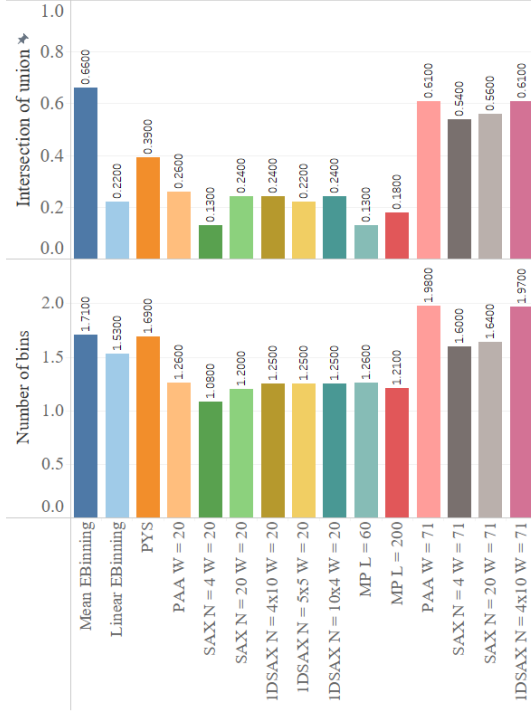(b) Sample of triangle-wave transient pattern with 1σ and 100 duration
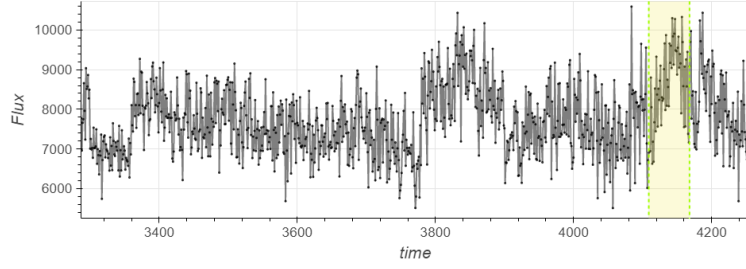
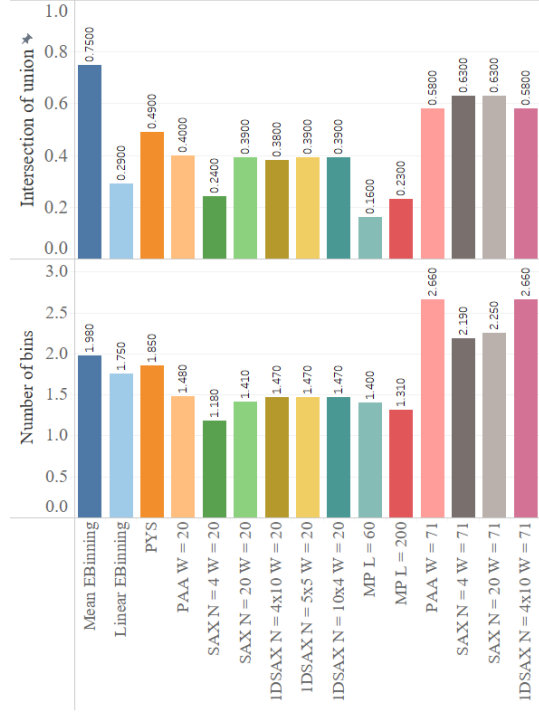(c) Sample of triangle-wave transient pattern with 1σ and 60 duration

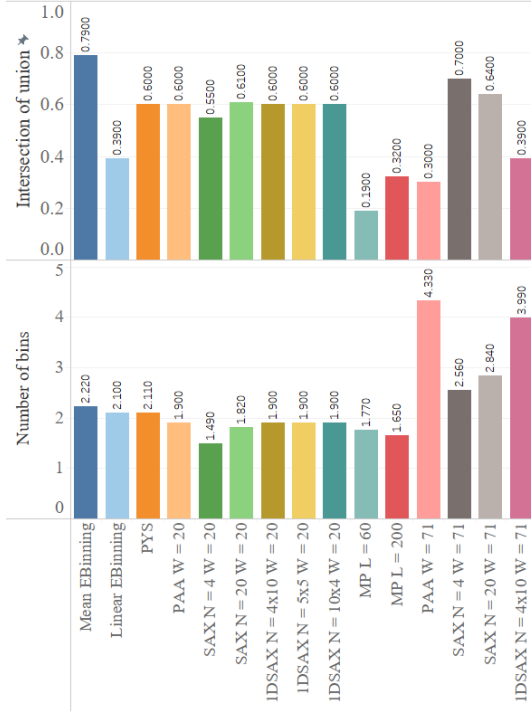(d) Sample of triangle-wave transient pattern with 1σ and 100 duration

Figure 6: Samples of short duration and small height of triangle-wave transient pattern
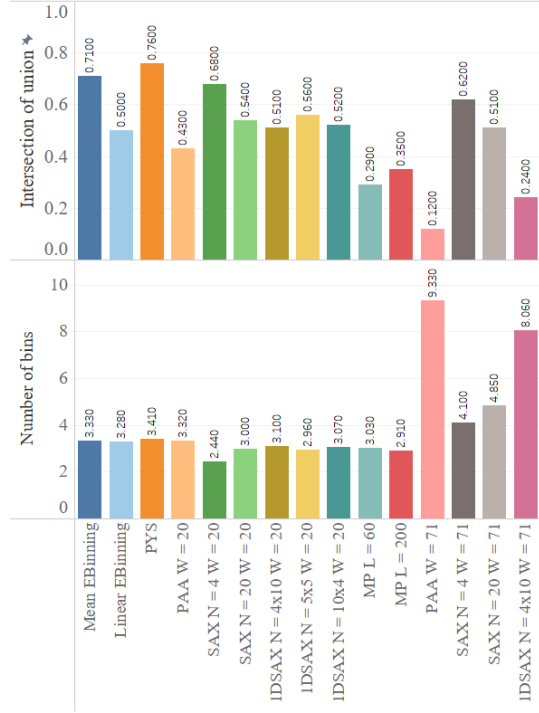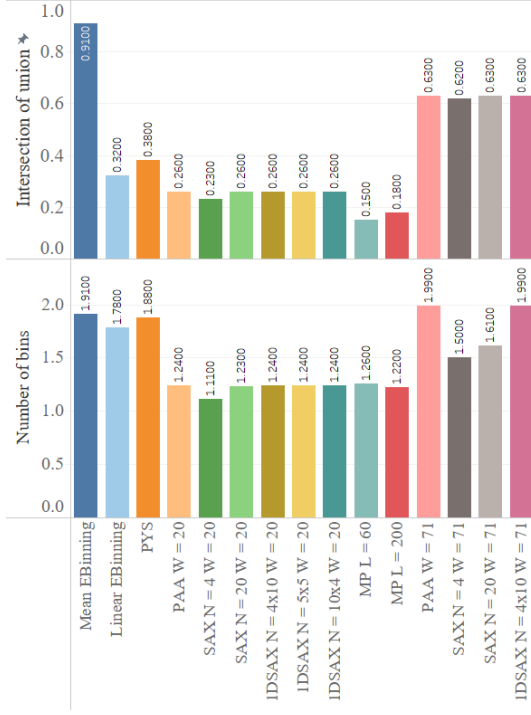
(a) Duration = 60

(b) Duration = 100

(c) Duration = 200
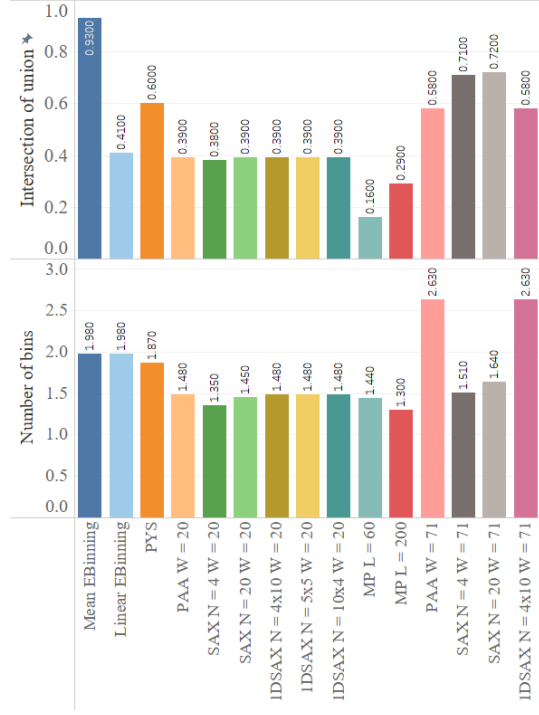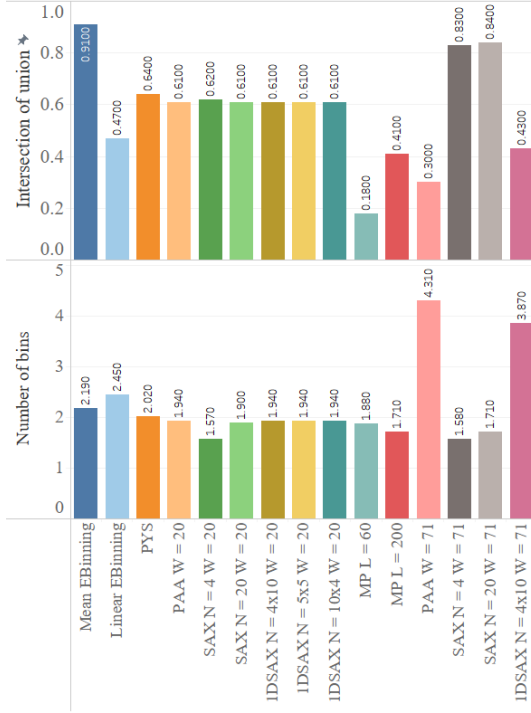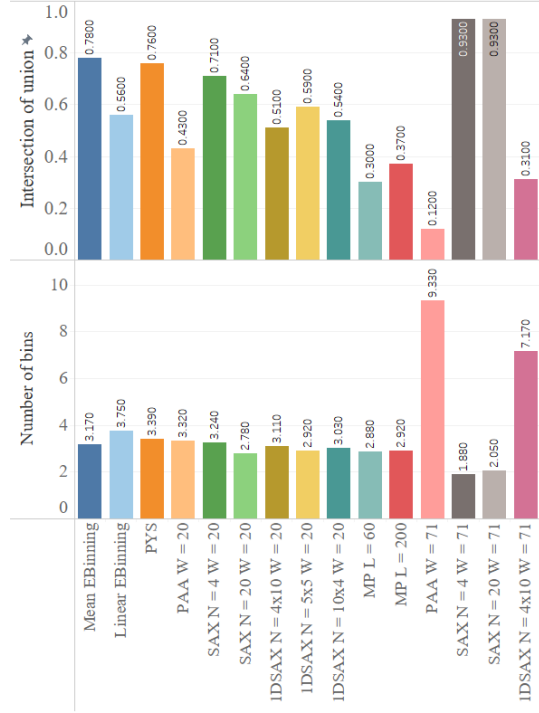
(d) Duration = 500

Figure 7: comparison results of intersection of Union (IOU) and average of bins for square-wave transient pattern (Height = 1σ)
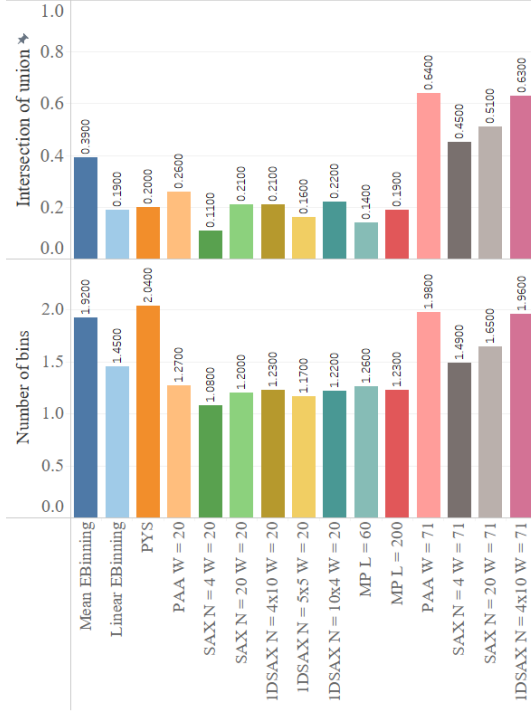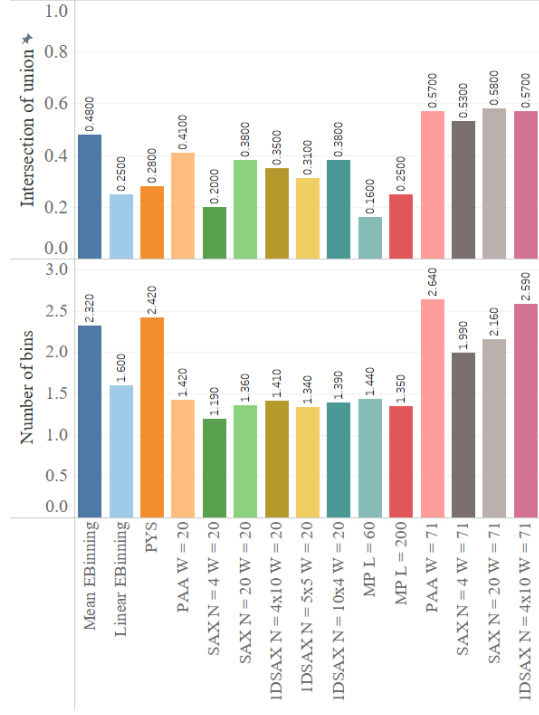
(a) Duration = 60

(b) Duration = 100

(c) Duration = 200

(d) Duration = 500

Figure 8: comparison results of intersection of Union (IOU) and average of bins for square-wave transient pattern (Height = 3σ)

(a) Duration = 60

(b) Duration = 100
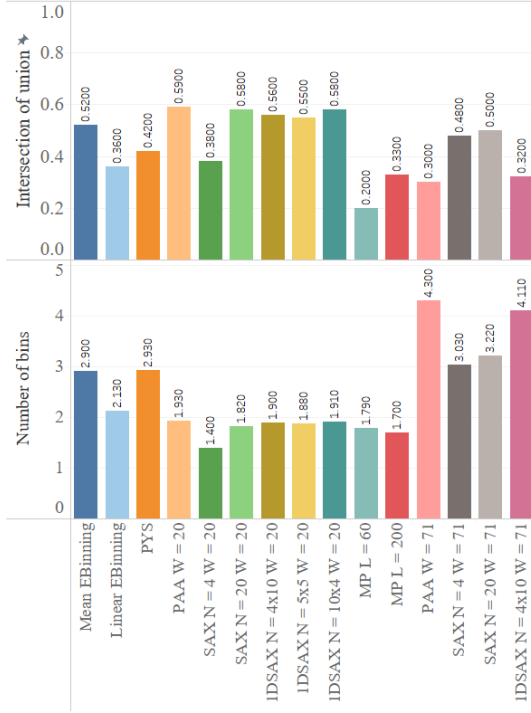
(c) Duration = 200

(d) Duration = 500

Figure 9: comparison results of intersection of Union (IOU) and average of bins for triangle-wave transient pattern (Height = 1σ)
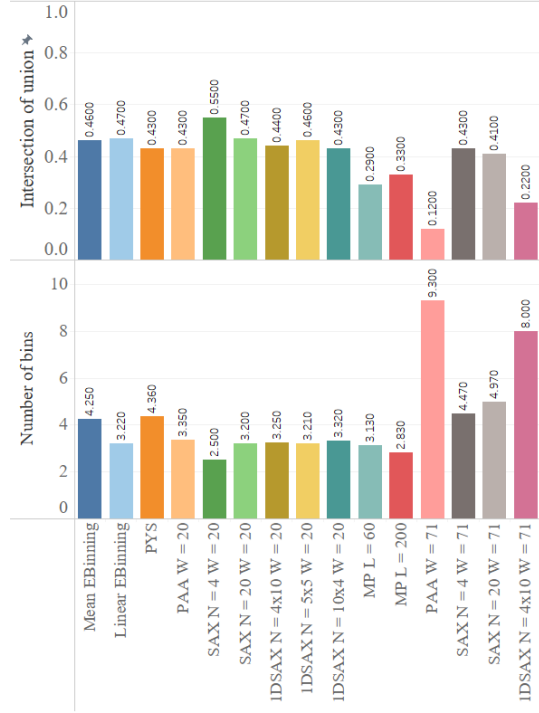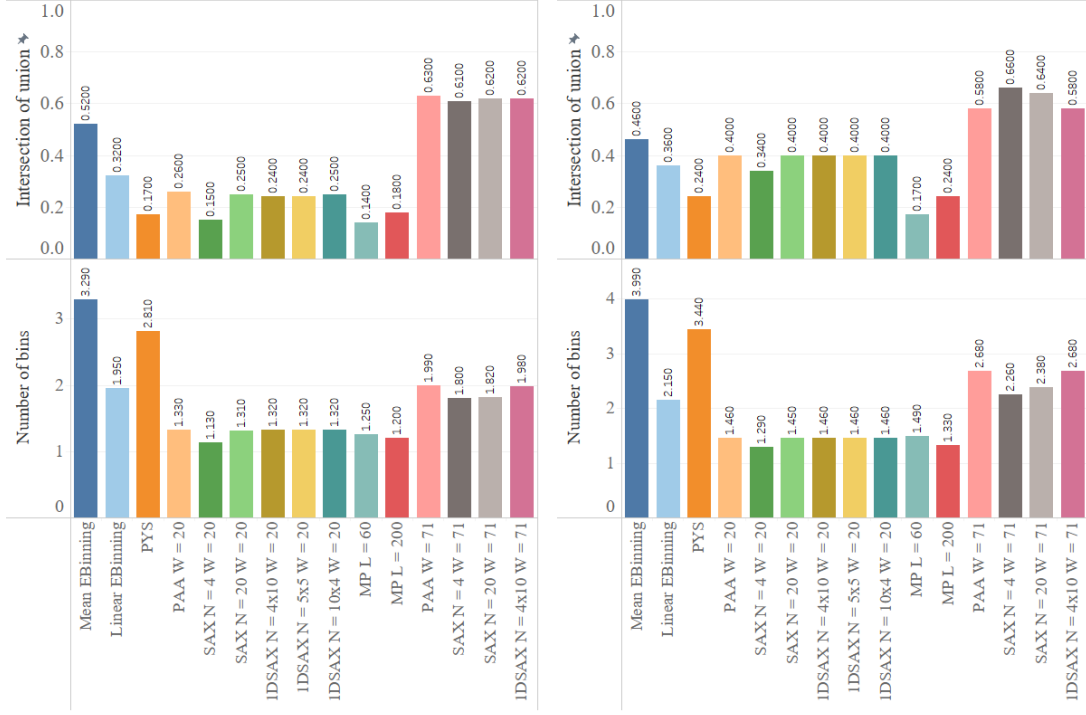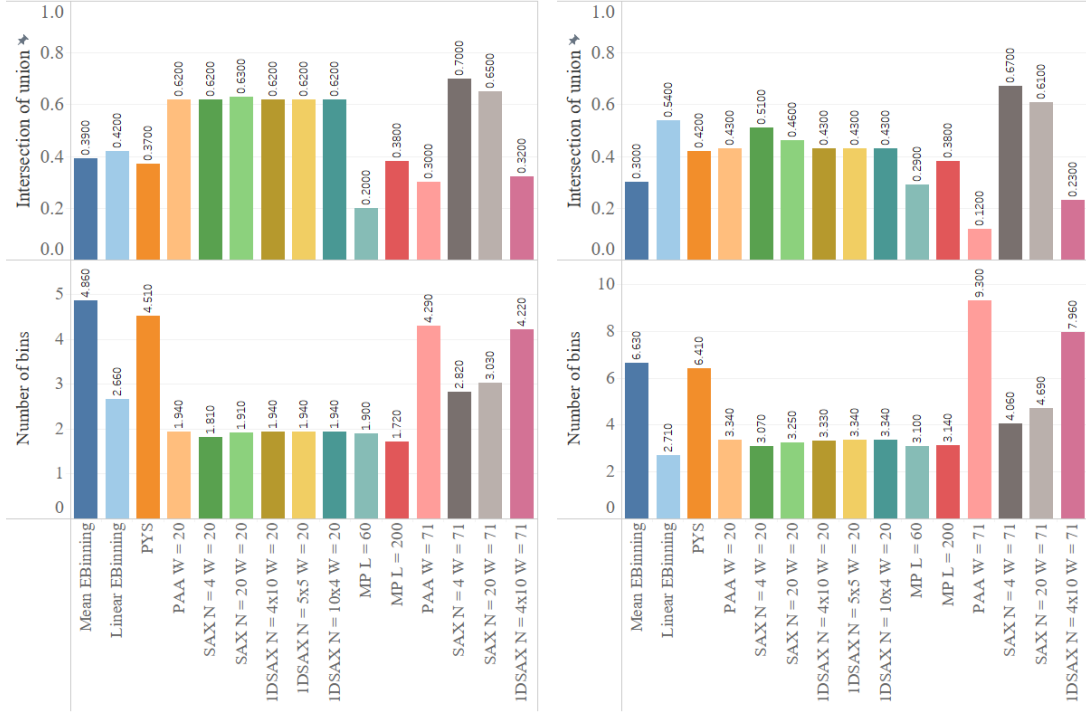
(a) Duration = 60

(b) Duration = 100

(c) Duration = 200

(d) Duration = 500

Figure 10: comparison results of intersection of Union (IOU) and average of bins for triangle-wave transient pattern (Height = 3σ)
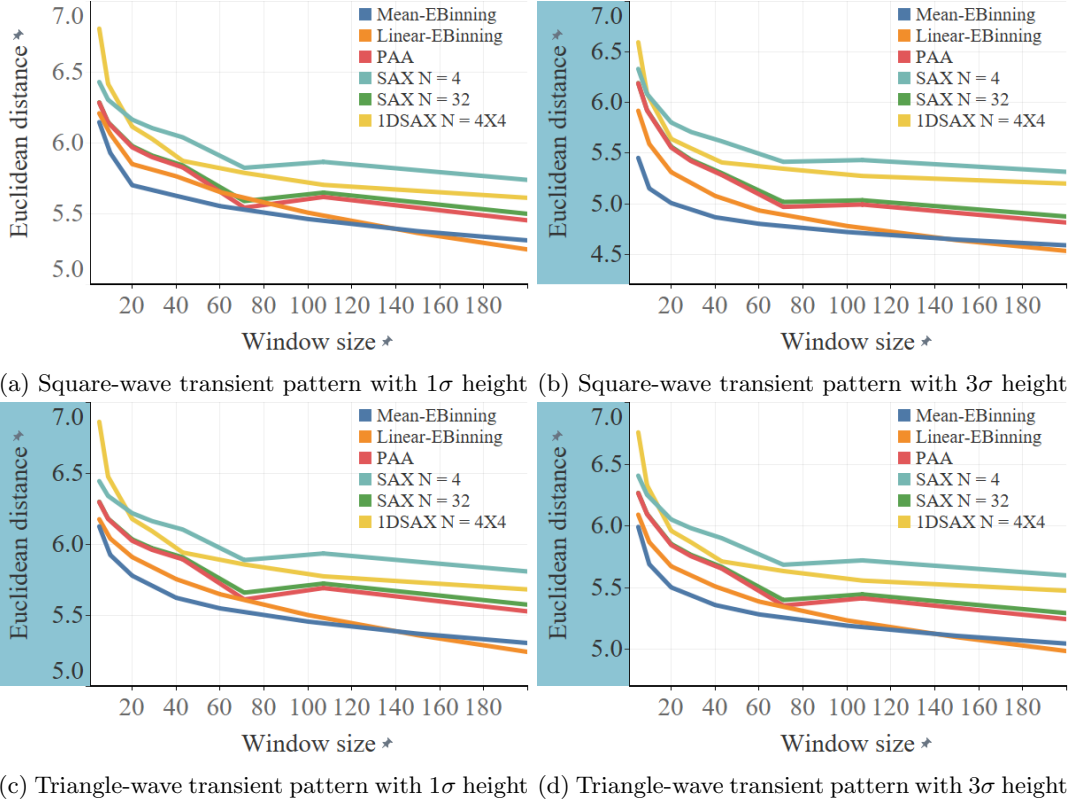
(a) Square-wave transient pattern with 1σ height (b) Square-wave transient pattern with 3σ height

(c) Triangle-wave transient pattern with 1σ height (d) Triangle-wave transient pattern with 3σ height

Figure 11: Comparison of Euclidean distance by various window size

(a) Square-wave transient pattern with 1σ height (b) Square-wave transient pattern with 3σ height

(c) Triangle-wave transient pattern with 1σ height (d) Triangle-wave transient pattern with 3σ height
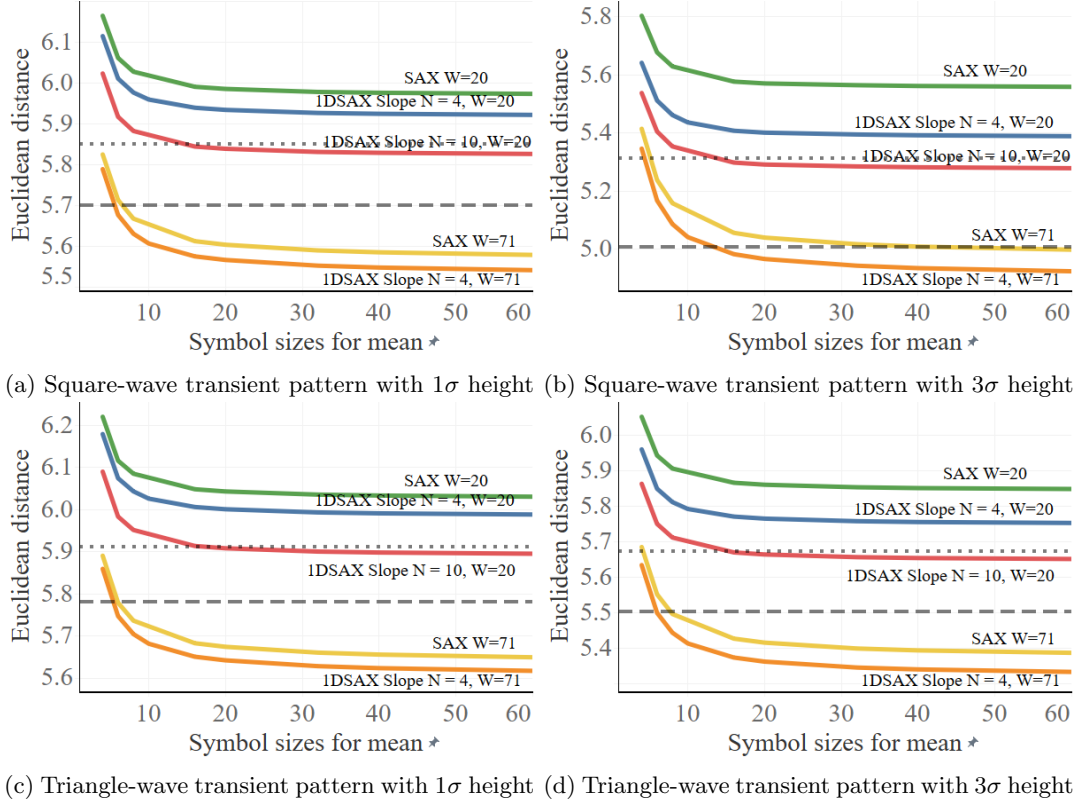
Figure 12: Comparison of Euclidean distance by various numbers of the symbols for means

(a) Square-wave transient pattern with 1σ height (b) Square-wave transient pattern with 3σ height

(c) Triangle-wave transient pattern with 1σ height (d) Triangle-wave transient pattern with 3σ height
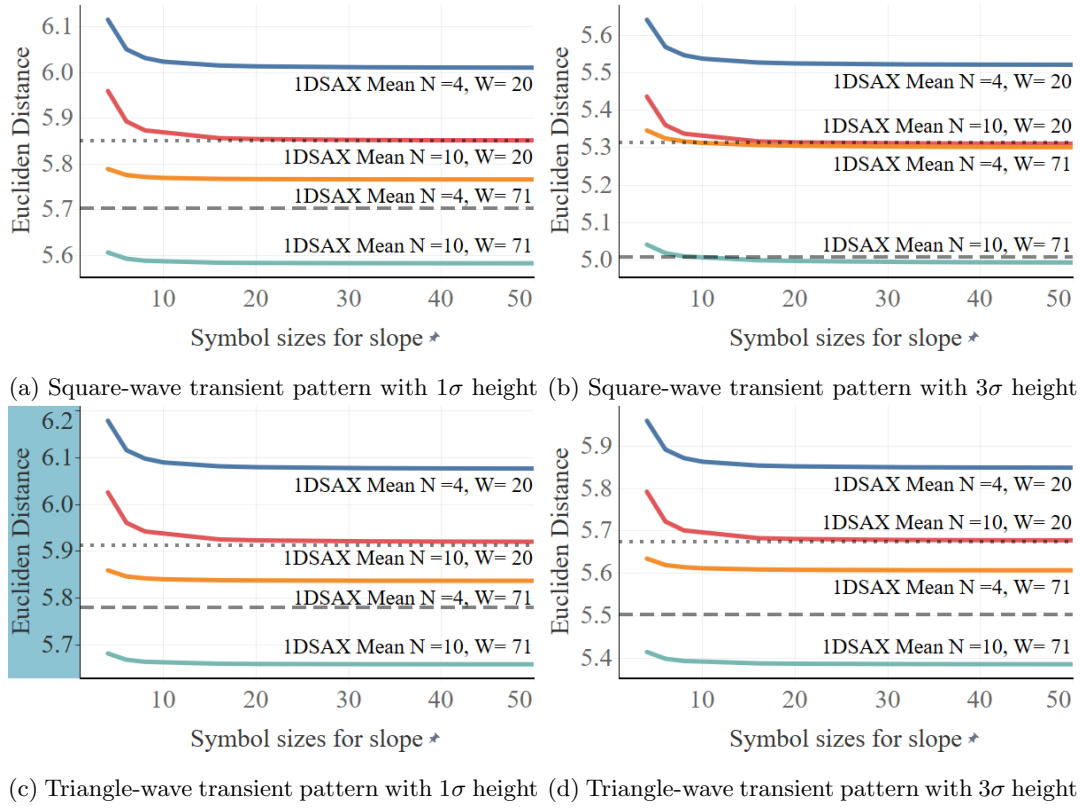
Figure 13: Comparison of Euclidean distance by various numbers of the symbols for means

3.3 Transient pattern detecting

This subsection presents the true-positive rate with various methods, heights, and durations of the transient patterns, as shown in Figures 14 - 17.
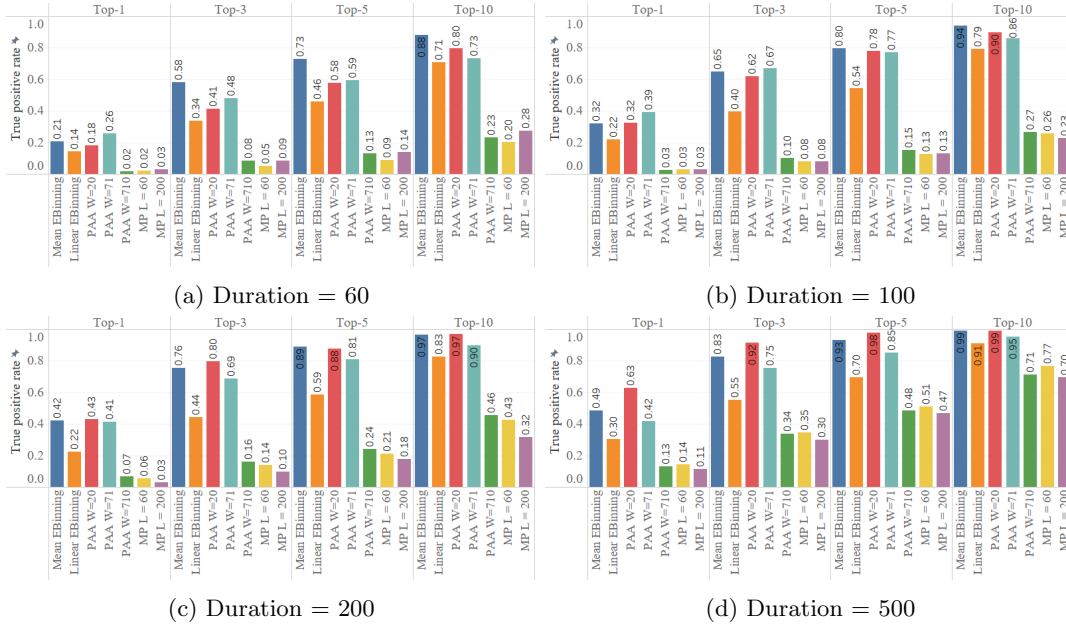
Figure 14: Comparison true positive rate with various detection methods for square-wave transient pattern (Height = 1σ)
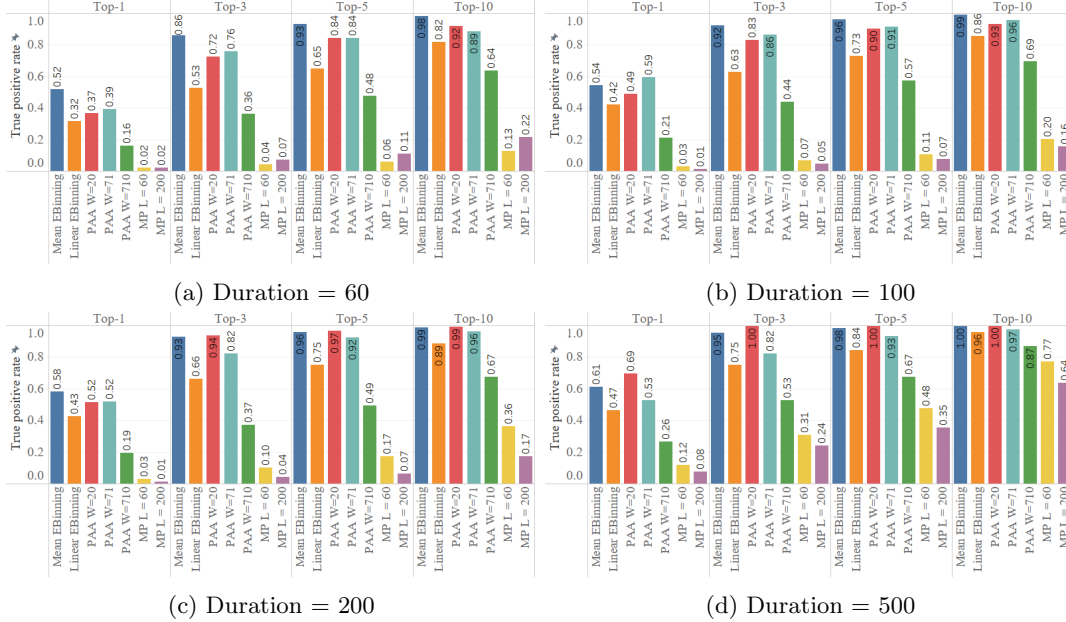

Figure 15: Comparison true positive rate with various detection methods for square-wave transient pattern (Height = 3σ)
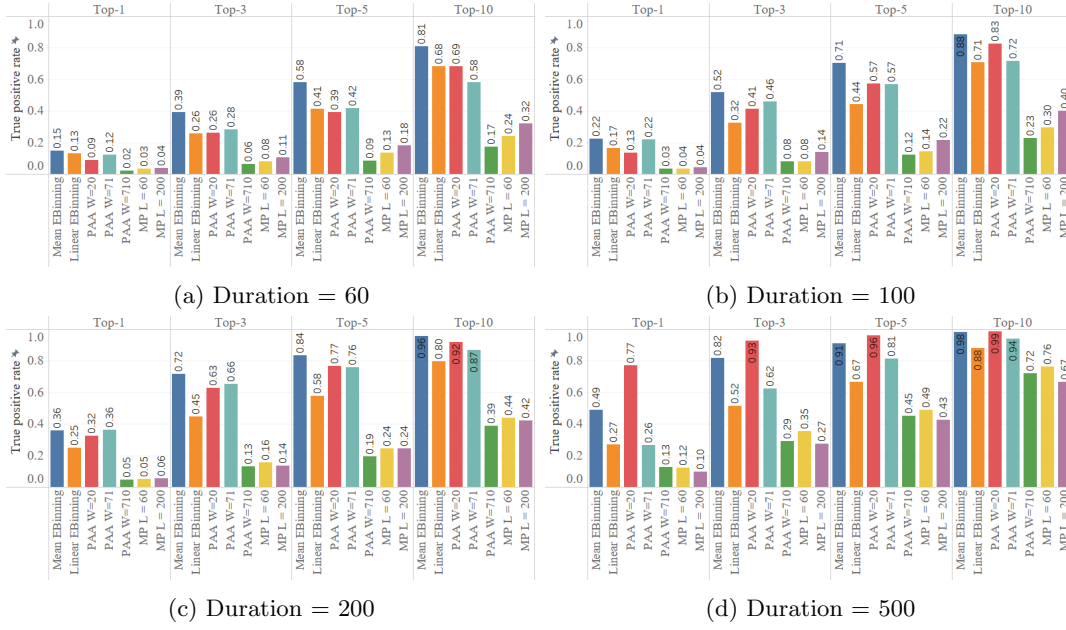
Figure 16: Comparison true positive rate with various detection methods for triangle-wave transient pattern (Height = 1σ)
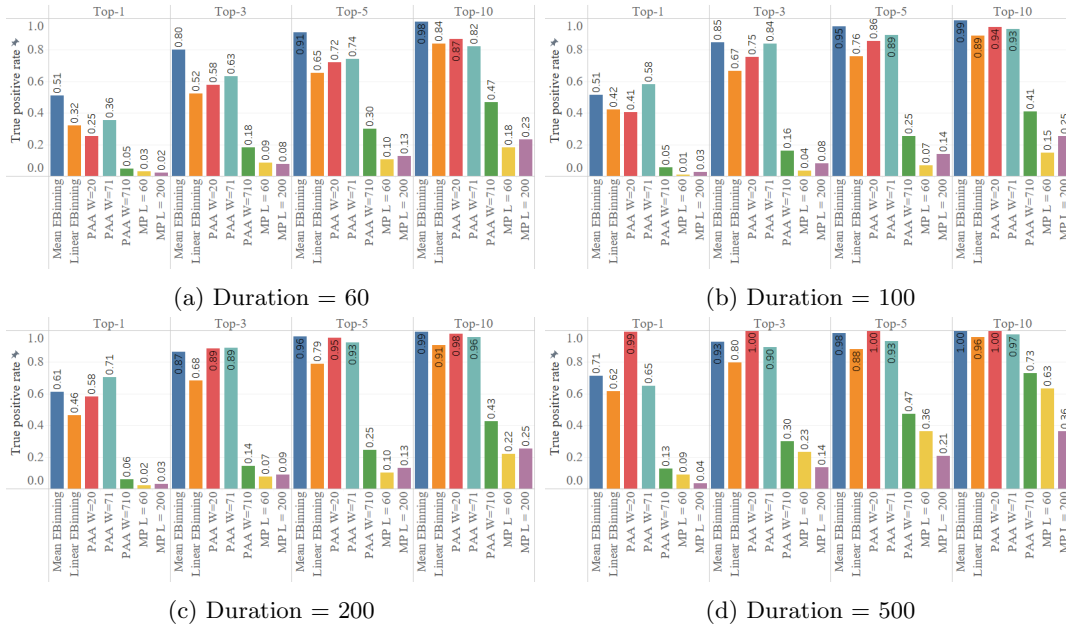

Figure 17: Comparison true positive rate with various detection methods for triangle-wave transient pattern (Height = 3σ)