Advances in Intelligent Systems and Computing

Volume 1401

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The publications within “Advances in Intelligent Systems and Computing” are primarily proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

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All books published in the series are submitted for consideration in Web of Science.

More information about this series at http://www.springer.com/series/11156
16th International Conference on Soft Computing Models in Industrial and Environmental Applications (SOCO 2021)
Preface

This volume of *Advances in Intelligent and Soft Computing* contains accepted papers presented at the *16th International Conference on Soft Computing Models in Industrial and Environmental Applications* (SOCO 2021). This conference was held in the beautiful seaside city of Bilbao, Spain, in September 2021.

Soft computing represents a collection or set of computational techniques in machine learning, computer science, and some engineering disciplines, which investigate, simulate, and analyze very complex issues and phenomena.

After a through peer-reviewed process, the SOCO 2021 International Program Committee selected 78 papers which are published in these conference proceedings and represents an acceptance rate of 48%. In this relevant edition, a special emphasis was put on the organization of special sessions. Seven special sessions were organized related to relevant topics as: Applications of machine learning in computer vision; soft computing applied to autonomous robots and renewable energy systems; optimization, modeling and control by soft computing techniques; challenges and new approaches toward artificial intelligence deployments in real-world scenarios; time series forecasting in industrial and environmental applications; soft computing methods in manufacturing and management systems; and applied machine learning.

The selection of papers was extremely rigorous in order to maintain the high quality of the conference, and we would like to thank the members of the program committees for their hard work in the reviewing process. This is a crucial process to the creation of a high standard conference, and the SOCO conference would not exist without their help.

SOCO 2021 enjoyed outstanding keynote speeches by distinguished guest speakers: Prof. Javier del Ser, who is a principal researcher in data analytics and optimization at Tecnalia, Spain, and is a part-time lecturer at the University of the Basque Country, Spain; Prof. Concha Bielza, who is a full professor in the Department of Artificial Intelligent, Polytechnic University of Madrid, Spain; and Prof. Enrique Zuazua, who holds a chair in Applied Analysis at Friedrich Alexander University, Germany, and a chair of Computational Mathematics at University of Deusto, Spain.
SOCO 2021 has teamed up with “Neurocomputing” (Elsevier) and “Logic Journal of the IGPL” (Oxford University Press) for a suite of special issues including selected papers from SOCO 2021.

Particular thanks go as well to the conference main sponsors, Startup Ole, Department of Education and Universities of the Basque Government, Logistar Project of DeustoTech, and University of Deusto, who jointly contributed in an active and constructive manner to the success of this initiative.

We would like to thank all the special session organizers, contributing authors, as well as the members of the program committees and the local organizing committee for their hard and highly valuable work. Their work has helped to contribute to the success of the SOCO 2021 event.

September 2021

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Machine Learning
A Comparison of Techniques for Virtual Concept Drift Detection

Manuel L. González\textsuperscript{1(✉)}, Javier Sedano\textsuperscript{1}, Ángel M. García-Vico\textsuperscript{2}, and José R. Villar\textsuperscript{3}

\textsuperscript{1} Instituto Tecnológico de Castilla y León, Burgos, Spain  \\ \{manuel.gonzalez,javier.sedano\}@itcl.es  
\textsuperscript{2} Andalusian Research Institute in Data Science and Computational Intelligence (DaSCI), University of Granada, Granada, Spain  \\ agvico@decsai.ugr.es  
\textsuperscript{3} University of Oviedo, Oviedo, Spain  \\ villarjose@uniovi.es  
\url{http://www.itcl.es}

Abstract. Concept Drift is one of the main problems presents in data stream processing for Data Mining and Machine Learning. This study focuses on Virtual Concept Drift. A common approach includes i) the detection of the drift with a specialized algorithm, and ii) the adaptation of the model to the current scenario. This work studies how well-known pre-processing methods affect abrupt Virtual Concept Drift detection in data streams. The proposed pre-processing techniques are: i) deleting the trend and ii) transforming the data stream from time to spectral domain. Moreover, three Virtual Concept Drift detection methods are compared over three publicly available data sets. According to the results, a slight improvement in the detection of Virtual Concept Drift is achieved when the trend is deleted. In contrast, no detection of Virtual Concept Drift is reported on the spectral domain.

Keywords: Data stream mining · Concept Drift detection · Pre-processing methods

1 Introduction

Nowadays, the exponential increase of IoT devices and sensors is generating a continuous information flow. This continuous flow of data is commonly known as a data stream [1]. The general characteristics of data streams imply a challenge for Data Mining and Machine Learning [2]. The main constraints imposed by data stream mining are the processing time, system memory and the adaptability
of the algorithms. In this context of adaptability, algorithms have to deal with the constantly evolving nature of data. This phenomenon is known as Concept Drift (CD) [3] and leads to a decrease in model performance over time for any given task [4–6]. Conceptually, CD happens when the joint probability distribution, \( p(X, y) \), for the same pair of input and output data streams, \( X \) and \( y \), changes in time: \( p_t(X, y) \neq p_{t+1}(X, y) \) [7].

Based on its source, CD can be classified into two different types [8]. i) Real Concept Drift (RCD), where the change over time is in the relationships between input and output data, represented by the evolution of conditional probability distributions \( p_t(y|X) \neq p_{t+1}(y|X) \). ii) Virtual Concept Drift (VCD), where the change over time is in the distributions of the input data, \( p_t(X) \neq p_{t+1}(X) \). Another dimension of CD is the type and velocity of the changes over time. Four classes of CD can be distinguished in this regard [8]: abrupt, gradual, incremental and recurring.

Two common approaches are developed to deal with CD. In one of them, the model is continuously updated by the new incoming data. Whereas in the other, the CD is firstly detected, with a specialized algorithm, and then the model has adapted consequently. In this study, is considered the second approach, mainly in CD detection.

Algorithms specialized in CD detection can be divided into two categories, depending on the CD source. i) RCD detection methods, which are mainly focused on the model’s accuracy change [5,6,13,14]. ii) VCD detection methods (VCD-DMs), focused on the change in input data stream statistical properties [11,12,17]. There is a vast amount of research papers about CD detection [2,4,8–10]. Depending on the CD type and velocity of change over time, some detection methods show better performance than others [2].

The majority of studies in the literature are focused on RCD detection because these algorithms directly measure the decrease in model accuracy. VCD-DMs become interesting since the real output variable \( y \) is, in many cases, unknown -thus RCD is not possible-. Some descriptive Data Mining techniques with this problematic are clustering and association rules. Furthermore, the study and detection of VCD allow measuring changes in the input data distributions over time, favouring the model to be updated and tuned early on. Therefore, interest in VCD is justified.

In Data Mining methodology, it is common to apply a pre-processing method (PPR-M) to the input data stream before any processing algorithm [15]. These techniques aim to remove noise or unwanted properties from the data, to add information from other sources or to adapt the input data stream for the processing algorithms.

This study focuses on the detection of abrupt VCD on data streams. This research aims to compare some of the most known techniques for VCD detection, together with different PPR-Ms. This study tries to answer the following questions:

1. How does the VCD-DMs vary if the trend is filtered by a PPR-M?
2. How does the VCD-DMs work in the spectral domain?
3. Which are the differences among VCD-DMs when using the same PPR-M?
4. How is the performance of the VCD-DMs techniques affected by the nature of the sliding window?

The rest of the paper is organized as follow: the next section describes the PPR-Ms and VCD-DMs techniques to be studied in the comparison. The data sets and experimental setup are detailed in Sect. 3. Section 4 depicts the obtained results and discusses the answers to the questions previously formulated. Finally, the study ends with the conclusions and future work.

2 A Description of the Technologies

As shown in Fig. 1, the most common approach in data stream mining to extract knowledge from drifting data is described below.

1. The arriving data is buffered creating chunks of data of a pre-defined length.
2. PPR-M is applied to the data chunk.
3. When selected, a CD detection method is performed; if CD is detected, then the model is adapted in consequence.
4. Run the adapted model to obtain some knowledge from evolving data.

![Fig. 1. Scheme of a system adapted to Concept Drift](image)

This section outlines the PPR-Ms that are considered in this study, as well as the VCD-DMs to be compared.

2.1 Pre-processing Alternatives

Let $X(t)$ be the input data stream. Up to four different standard and well-known PPR-Ms are used in this study, which are listed below.

1. **Identity (ID):** $X(t) \rightarrow X(t)$, in essence, it does not transform the original data stream.
2. **Calculate Local Derivative (LDV):** $X(t) \rightarrow \frac{(X(t) - X(t - 1))}{\Delta t}$, where $\Delta t$ is the local increment in time defined as $\Delta t = t_i - t_{i-1}$.
3. **Subtract Simple Moving Average (S-SMA):** $X(t) \rightarrow X(t) - SMA(X(t))$, where $SMA$ stands for Simple Moving Average.
4. **Calculate Spectral Distribution (SDT):** \(X(t) \rightarrow \tilde{X}(f)\), Discrete Fourier Transform (DFT) \([16]\) will be used to transform data stream from time-domain \(-X(t)-\) to frequency-domain \(-\tilde{X}(f)-\).

The first method has been proposed to have a comparison baseline. The second and third ones aim to remove the trend from the data stream. It is worth noticing that the latter transformation normalizes seasonal components of the data stream by changing to the spectral domain. For a comprehensive study on PPR-Ms for CD see \([15]\).

### 2.2 Virtual Concept Drift Detection Methods

The majority of the VCD-DMs proposed in the literature are based on the comparison of the statistical properties between different portions of the data stream. These portions are called windows of data. A window of data \(W\) on input data stream \(X(t)\) is considered a time-ordered subset of consecutive elements \(x \in X(t)\) that acts as a buffer. These windows can have fixed or variable length and their elements may vary over time. Depending on the number of windows and their properties, different VCD-DMs have been developed \([2,9]\). According to the results in \([2]\), two-windows-based VCD-DMs show better performance for abrupt VCD detection than other alternatives. Therefore, the proposed methods in this study belong to this category. These methods are: Adaptive sliding window algorithm (ADWIN) \([17]\), Kolmogorov-Smirnoff Test (KS-Test) \([19]\) and Fourier Inspired Windows for Concept Drift detection (FIWCD) \([21]\).

Let \(W_t\) be a window of data at time \(t\) on \(X(t)\). Let \(W_t^O\) and \(W_t^R\) be two subwindows of data on \(X(t)\). Their lengths are \(n^O\) and \(n^R\), respectively, and \(W_t^R\) is the most recent of the two. We denote \(W_t = W_t^O \cup W_t^R\) with length \(n\), where \(n\) accomplishes Eq. 1, which means, there could be an overlap between the two subwindows. The lengths of \(W_t^O\) and \(W_t^R\) may vary according to the current VCD-DM, but Eq. 1 must be always satisfied.

\[
n \leq n^O + n^R
\]  

In these conditions, it is considered that VCD has happened whenever remarkable differences are found among the descriptive statistics calculated for each subwindow \([17]\). The chosen methods follow two different strategies to detect the existence of a remarkable difference: to set some specific bound base on confidence level \(\alpha\), like ADWIN or KS-Test, or to set a similarity threshold \(\lambda\) like FIWCD.

It should be noted that no underlying model is needed for these detection methods, so it can be applied to any system that computes data streams. In the following sections, the proposed methods are going to be explained. It should be highlighted that the notation is slightly different from that of the original papers to unify it.