Optimal Event Monitoring through Internet Mashup over Multivariate Time Series

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ABSTRACT

The authors propose a Web-Mashup Application Service Framework for Multivariate Time Series Analytics (MTSA) that supports the services of model definitions, querying, parameter learning, model evaluations, data monitoring, decision recommendations, and web portals. This framework maintains the advantage of combining the strengths of both the domain-knowledge-based and the formal-learning-based approaches and is designed for a more general class of problems over multivariate time series. More specifically, the authors identify a general-hybrid-based model, MTSA – Parameter Estimation, to solve this class of problems in which the objective function is maximized or minimized from the optimal decision parameters regardless of particular time points. This model also allows domain experts to include multiple types of constraints, e.g., global constraints and monitoring constraints. The authors further extend the MTSA data model and query language to support this class of problems for the services of learning, monitoring, and recommendation. At the end, the authors conduct an experimental case study for a university campus microgrid as a practical example to demonstrate our proposed framework, models, and language.

Keywords: Decision Support, Optimization Model, Parameter Learning, Query Language, Web-Mashup Framework

INTRODUCTION

Observing behaviors, trends, and patterns on multivariate time series (Bisgaard & Kulahci, 2011; Chatfield, 2001) has been broadly used in various application domains, such as financial markets, medical treatments, economic studies, and electric power management. Domain experts utilize multiple time series to detect events and make better decisions. For example, financial analysts predict different states of the stock market, e.g., bull or bear, more accurately based upon monitoring daily stock prices, weekly interest rates, and monthly price indices. Physicians monitor patients’ health conditions by measuring their diastolic and systolic blood pressures, as well as their electrocardiogram tracings over time. Sociologists uncover hidden social problems within a community more pro-

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foundly through studying a variety of economic, medical, and social indicators, e.g., annual birth rates, mortality rates, accident rates, and various crime rates. The goal of examining those characteristics over multivariate time series on events is to support decision makers, e.g., financial analysts, physicians, and sociologists, to better understand a problem in different perspectives within a particular domain and to offer better actionable recommendations.

To support such an event-based decision-making and determination over multivariate time series, in this paper, we propose a Web-Mashup Application Service Framework for Multivariate Time Series Analytics (MTSA). This framework is an integrated tool to support the MTSA service development, including model definitions, querying, parameter learning, data monitoring, decision recommendations, and model evaluations. Domain experts could use the framework to develop and implement their web-based decision-making applications on the Internet. Using a Web Mashup function offered by the Web 2.0 technology (Vancea & Others, 2008; Gurram & Others, 2008; Murugesan, 2007; Bradley, 2008; Alonso & Others, 2004; Altinel & Others, 2007; Ennals & Others, 2007; Thor & Others, 2007) on our framework, domain experts could collect and unify global information and data from different channels and media, such as web sites, data sources, organizational information, etc., to generate a concentric view of collected time series data from which the learning service determines optimal decision parameters. Using optimal decision parameters, domain experts can employ the monitoring service to detect events and the recommendation service to suggest actions.

Presently, there are two key approaches that domain users utilize to identify and detect interesting events over multivariate time series. These approaches are domain-knowledge-based and formal-learning-based. The former approach completely relies on domain experts’ knowledge. Based on their knowledge and experience, domain experts determine monitoring conditions that detect events of interest and trigger an appropriate action. More specifically, domain experts, e.g., financial analysts, have identified several deterministic time series, such as the S&P 500 percentage decline time series, from which they develop parametric monitoring templates, e.g., SPD < -20%, CCD < -30 (Stack, 2009), etc., according to their expertise. Once the incoming time series, i.e., SPD and CCD, satisfy the given templates at a particular time point, the financial analysts decide that the bear market bottom is coming, which is the best buy opportunity to purchase the stock to earn the maximal earning.

Consider another real-world case study of the timely event detection of certain conditions in the electric power microgrid at George Mason University (GMU), where its energy planners would like to regularly detect when the electric power demand (electricPowerDemand) exceeds the pre-determined peak demand bound (peakDemandBound). The reason is that the occurrence of this event leads to a significant portion of the GMU electric bill based upon its contractual terms even though the event, electricPowerDemand > peakDemandBound, occurs only within a short period of time, e.g., one minute. Thus such an identification and detection can aid in the task of decision-making and the determination of action plans. To make better decisions and determinations, the energy planners have identified a set of time series that can be used to detect the event and perform an action, e.g., to execute the electric load shedding to shut down some electric account units on the GMU campus according to a prioritization scheme from the energy manager. The multiple time series include the input electric power demand per hourly time interval, the given peak demand bound per monthly pay period, etc. If these time series satisfy a pre-defined, parameterized condition, e.g., electricPowerDemand > peakDemandBound, where the given peakDemandBound is 17200 kWh for all the hourly time intervals within the same monthly pay period, e.g., July, 2012, it signals the energy planners to execute the electric load shedding in the microgrid on the campus. Often these parameters, e.g., the predetermined peak
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