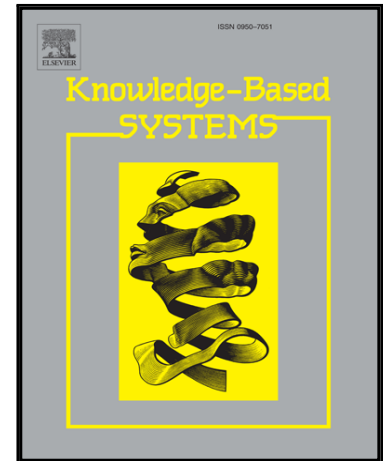


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Online Reliability Time Series Prediction via Convolutional Neural Network and Long Short Term Memory for Service-Oriented Systems

Hongbing Wang, *Member, IEEE*, Zhengping Yang, Qi Yu, Tianjing Hong, Xin Lin

Abstract—With the development of Web service technology, more and more enterprises choose to publish their own services on the Internet. However, with the increasing demands of users, it is difficult for a single service to meet the complex user requirements. To address this challenge, multiple services can be integrated by leveraging the service-oriented architecture (SOA) to generate a value-added service, referred to a service composition, where the component services are loosely coupled. However, due to the dynamic running environment, the performance of each component service (including reliability) may fluctuate. This will introduce cascading effects, which could cause the entire service system to fail. Since component services run in a dynamic environment, the parameters used to conduct reliability prediction are difficult to obtain. Therefore, online reliability prediction that ensures the runtime quality poses a grand challenge. This paper analyzes the historical response time time series and throughput time series of component services, and predicts the reliability in the near future. To guarantee the stable and continuous operation of a service system, we proposed an online reliability time series prediction method by combining a Convolutional Neural Network (CNN) and Long Short Term Memory (LSTM). The proposed approach, referred to as CL-ROP, is able to predict the reliability of a service system in the near future. We conducted a series of experiments over real service data and compared with other competitive approaches to demonstrate the effectiveness of the proposed approach.

Index Terms—Service Systems; Time Series; Online Reliability Prediction; Neutral Networks

1 INTRODUCTION

Nowadays, with the increasing demand for large-scale software systems, System of Systems (SoS) which integrates existing component systems into a value-added and more complex one can satisfy users' complex demands [1], [2]. Service-Oriented Architecture (SOA) has been widely adopted to build a service-oriented SoS [3]. Similar to SOA, a service-oriented SoS emphasizes the interaction, collaboration, and communication among the component systems. Given the loosely coupled relationships among the component systems, it is important to monitor, detect and protect the status of systems. However, the component systems may run in a highly dynamic environment due to multiple contributing factors, such as the unstable network. As a result, the runtime quality of a service-oriented SoS can not be guaranteed because the changes of individual component systems may cause a cascading effect so that the whole system may fail [4]. Therefore, the runtime quality assurance for a service-oriented SoS arises as an important research topic. As an example, Proactive

Fault Management (PFM) was proposed to make sure the stable and continuous operation of a service-oriented SoS [5]. PFM requires the component systems to be selected optimally [6] and it takes the reliability of component systems into consideration which introduces new challenges to the existing approaches. In order to support self-optimization, the reliability prediction should be conducted in a nearly real-time (or online) fashion, which can forecast the reliability in the near future.

The duration time of each invoked component system may vary from one to another as different users act differently and the communication links may be unstable. In addition, the reliability may fluctuate when a component is under invocation [7]. In order to address the challenges above, the online reliability prediction approach should manage the changes of variable prediction period. In most cases, when a predetermined prediction period is long enough, we can divide it into multiple intervals and predict the reliability of those time periods, referred to as the *reliability time series*. In other words, the main goal of online reliability prediction for service-oriented SoS is to predict the time series of the future period of time, based on current system state and historical records.

Most existing online fault prediction methods are designed for traditional systems that are not complex as a service-oriented SoS, which typically runs in a highly dynamic operating environment. Existing approaches primarily rely on statistical analysis historical records

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