# Chapter 70
# Cognitive Visual Analytics of Multi-Dimensional Cloud System Monitoring Data

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## ABSTRACT

*Hardware virtualization has enabled large scale computational service delivery models with high cost leverage and improved resource utilization on cloud computing platforms. This has completely changed the landscape of computing in the last decade. It has also enabled large–scale data analytics through distributed high performance computing. Due to the infrastructure complexity, end–users and administrators of cloud platforms can rarely obtain a full picture of the state of cloud computing systems and data centers. Recent monitoring tools enable users to obtain large amounts of data with respect to many utilization parameters of cloud platforms. However, they fail to get the maximal overall insight into the resource utilization dynamics of cloud platforms. Furthermore, existing tools make it difficult to observe large-scale patterns, making it difficult to learn from the past behavior of cloud system dynamics. In this work, the authors describe a perceptual-based interactive visualization platform that gives users and administrators a cognitive view of cloud computing system dynamics.*

DOI: 10.4018/978-1-7998-5339-8.ch070

## INTRODUCTION

Recently, the number of companies and institutions migrating their services to cloud providers has rapidly increased. Cloud computing platforms have largely improved the energy and device utilization of computing platforms. Furthermore, cloud computing has also provided flexible hardware and software configurations, elasticity, and performance isolation.

The on-demand computing service scheme enables customers to access computational resources via Internet, anytime, anywhere, via any smart device, tablet, phone, laptops, etc. For both providers and customers, the capital and operational cost is remarkably reduced relative to the utilization rates. However, the increasing number of cloud service providers, the types of cloud platforms, and their increased utilization rates, have resulted in complex infrastructure deployment, impeding their efficient management and support.

For a complete cloud system, essential features have to be taken into consideration, such as, availability, concurrency, dynamic load balancing security, etc. All these factors add to the operational complexity of cloud computing platforms for both providers and consumers. Hence, accurate monitoring tools and proper interfaces are paramount in order to manage hardware and software infrastructure.

Continuous monitoring presents important information, including workload generated by consumers and the performance and QoS (zakarya et al., 2012) offered through the cloud. Usually, computing platforms require both high-level and low-level monitoring (Giuseppe et al., 2012). High-level monitoring aims at collecting information on virtual platform status. For low-level monitoring, we are more concerned about the status of the physical infrastructure. Low level monitoring data is often available to providers but not exposed to customers.

Due to the increasingly complex infrastructure configurations of cloud systems, the monitoring metrics tend to compromise many of the embedded parameters, i.e. CPU, memory, temperature, voltage, workload, network traffic, etc. We note that resource utilization in a cloud system can be both virtual and physical. The real costs are incurred at the physical level. However, the virtual layer poses the real load onto the hardware platforms and, in many cases, the overload of the physical systems.

Some existing monitoring tools, such as Nagios (Nagios), provide traces of all the measurements and show their changes over time in the form of 2D graphs or diagrams. Although they provide thorough monitoring data collection, these tools are hardly suitable for finding global visual patterns that would give users cognitive insights into the data acquired. For example, users cannot be instantly aware of the machines behaving differently or being in similar states (e.g. zombie machines), the overall connectivity structures among machines, and the evolution of such structures. Furthermore, customers who do not engage in visual analytic techniques may not be perceptually cognizant in interpreting raw time series of numeric log data.

Our motivation stems from the lack of visual tools associated with these monitoring systems for modern elastic cloud platforms. We embark in search for a better visual access to global dynamic patterns in monitoring cloud data. The main challenge is that the analysis of the low-level data often cannot cope with the data generation speed and volume. Furthermore, other factors of data representation, such as the volume, and variety, also affect the process of deriving valuable information from monitoring cloud system dynamics.

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