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Low-cost high performance distributed data storage for multi-channel observations

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HIGHLIGHTS

- We compare storage technologies which have limitations on modern solar telescope.
- The first attempt to use distributed storage system (DSS) in real-time observation.
- The low-cost DSS can meet the requirements of NVST real-time observation.
- The number of simultaneously writing and the file size improve the performance of DSS.
- The different storage strategies have significant impacts on the access performance of DSS.

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ABSTRACT

The New Vacuum Solar Telescope (NVST) is a 1-m solar telescope that aims to observe the fine structures in both the photosphere and the chromosphere of the Sun. The observational data acquired simultaneously from one channel for the chromosphere and two channels for the photosphere bring great challenges to the data storage of NVST. The multi-channel instruments of NVST, including scientific cameras and multi-band spectrometers, generate at least 3 terabytes data per day and require high access performance while storing massive short-exposure images. It is worth studying and implementing a storage system for NVST which would balance the data availability, access performance and the cost of development. In this paper, we build a distributed data storage system (DDSS) for NVST and then deeply evaluate the availability of real-time data storage on a distributed computing environment. The experimental results show that two factors, i.e., the number of concurrent read/write and the file size, are critically important for improving the performance of data access on a distributed environment. Referring to these two factors, three strategies for storing FITS files are presented and implemented to ensure the access performance of the DDSS under conditions of multi-host write and read simultaneously. The real applications of the DDSS proves that the system is capable of meeting the requirements of NVST real-time high performance observational data storage. Our study on the DDSS is the first attempt for modern astronomical telescope systems to store real-time observational data on a low-cost distributed system. The research results and corresponding techniques of the DDSS provide a new option for designing real-time massive astronomical data storage system and will be a reference for future astronomical data storage.

1. Introduction

1.1. The New Vacuum Solar Telescope

The New Vacuum Solar Telescope (NVST) is a 1-m vacuum solar telescope of Fuxian Solar Observatory (FSO) which is located at the northeast side of Fuxian Lake, a world-class observational site in

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Yunnan province of China. The main tasks of the NVST are high resolution imaging and spectral observations in both the photosphere and the chromosphere, including measurements of the solar magnetic field (Liu and Xu, 2011; Liu et al., 2014).

The imaging system is a significant part of NVST. The main structure of NVST imaging system is a multi-channel high resolution imaging system and consists of one channel for the chromosphere and two channels for the photosphere. The wavelength band for observing the chromosphere is Hα (6563 Å). The bands for observing the photosphere are TiO (7058 Å) and the G-band (4300 Å). So far, there are five cameras, i.e., one Andor Neo sCMOS camera (2560 × 2160 pixel with 30 frames per second (FPS)), three PCO4000 CCD cameras (4008 × 2672 pixel with 5 FPS) and one PCO2000 camera (2048 × 2048 pixel with 14.7 FPS), are installed on NVST. All channels connect to an optical splitters so that these channels can observe and record images simultaneously. The fine structures and their evolution in the photosphere and the chromosphere can be observed at the same time.

Table 1 shows the requirements of storage bandwidth and the expected performance of the NVST storage system.

1.2. Current computer data storage technology

For astronomical observations, data storage technology is one of the most important issues because all of the data must be stored securely and reliably (and eventually archived intelligently) while remaining accessible on demand.

So far, Direct Attached Storage (DAS), Network Attached Storage (NAS) and Storage Area Network (SAN) are quite mutual. Fig. 1 shows the architecture diagrams of the data storage system (DSS) with DAS and NAS/SAN technique respectively. Meanwhile, the advent of new generation storage techniques (i.e., high performance Solid State Disk (SSD) system, massive clouding storage, high speed 8 Gb and higher storage bandwidth) brings more options for the massive and high performance astronomical data storage. We investigate the previous literatures concerning the astronomical data storage and list advantages and limitations of each technique respectively in Table 2.

Besides DAS, NAS and SAN techniques, distributed storage technique is becoming a trend for massive data storage. Distributed parallel file system is such a technique to survive massive data storage; it can provide high I/O performance and extensible bandwidth, and it can be scaled out to fit for petabyte level data storage (Braam, 2003). Distributed data storage systems have already been widely used in astronomy (Withington, 2004). Astro-WISE (http://www.astro-wise.org/) is a distributed system for astronomical data. It stores all kinds of data ranging from the raw data to the final science-ready product data (Mwebaze et al., 2010). Becla et al. (2006) utilized highly-distributed relational database and super massive databases to store astronomical data. Stonebraker et al. (2011) use non-relational database—SciDB (Cudré-Mauroux et al., 2009) to store astronomical data. SciDB is already applied in radio astronomy (Diepen, 2013). In order to deal with the large storage requirements of MAGIC-I and MAGIC-II, Carmona et al. (2009) exploited the distributed file system (GFS) and built a cluster of computers with concurrent access to the same shared storage units. This storage system has advantages such as reliability, flexibility and scalability. Gfarm distributed file system has been

Table 1
Cameras bandwidth requirements and the expected performance of the storage system.

Camera	Max. network bandwidth V_b (MB)	Average HDD data rate V_d (MB/s)	Size per frame S_f (MB)	Expected transport rate V_t (MB/s)	Expected image rate V_i (FPS)
Andor Neo	1250	156	11	330	30
PCO4000	125 × 3	156 × 3	21	105 × 3	5 × 3
PCO2000	125	156	8	117.6	14.7
Total				762.6	

Notes: each pixel is stored using two bytes; $V_t = S_f \times V_i$.

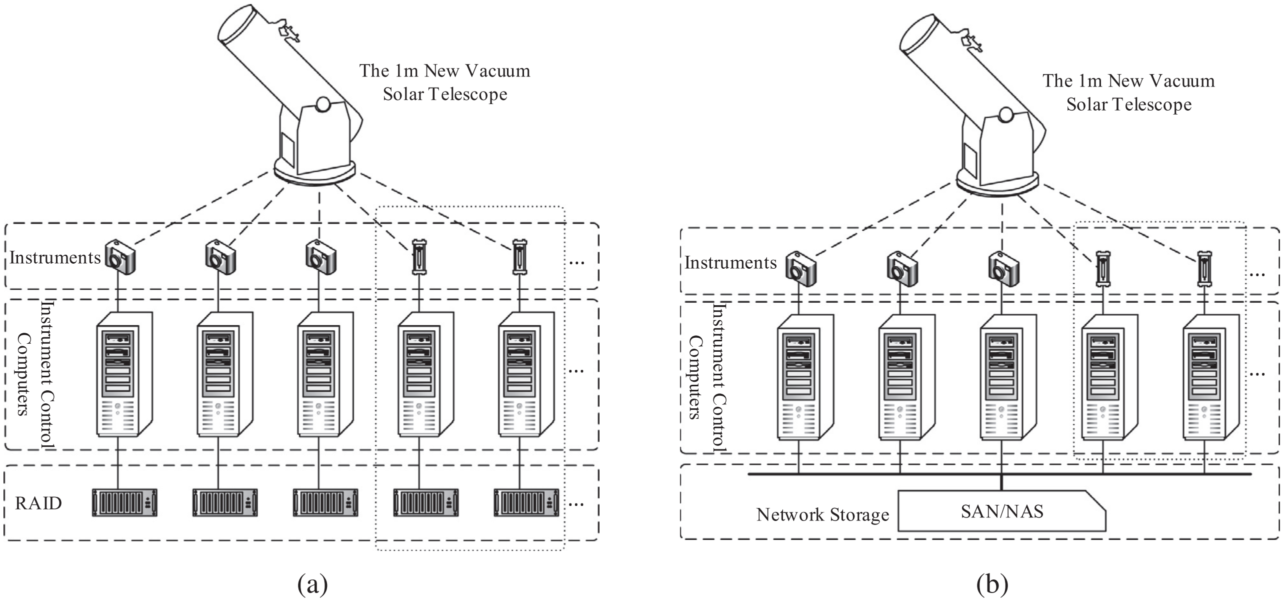

Fig. 1. The architecture diagram of the DSS with DAS and SAN/NAS technique. (a) shows a DAS architecture and (b) shows a common SAN/NAS architecture.