Searching Large Scientific Data

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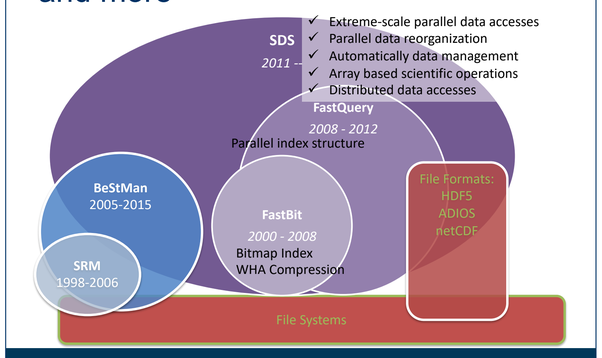
Overview

Data management is key in simulation and analysis for speed, memory and storage efficiency

- **Capability:** Premier group in algorithms and data structures, for data management, I/O and storage
- **Impact:** Improve applications performance, enable new science problems, more productive science
- **Stakeholders:** Application scientists and facilities; all SC, EERE, Health, and more



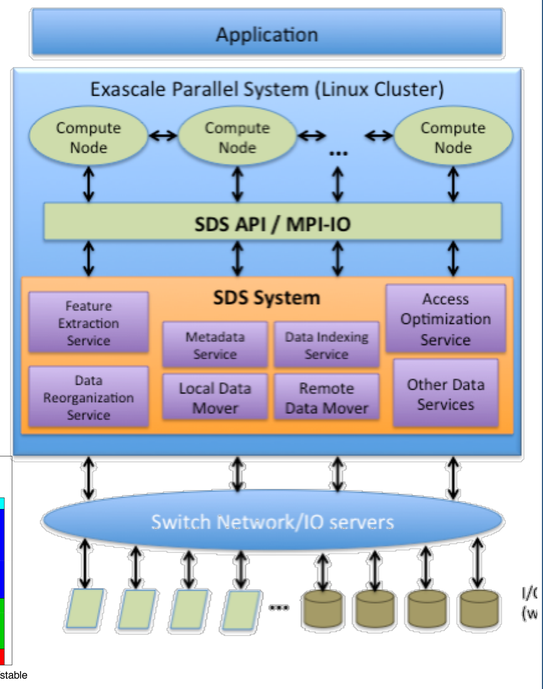
Scientific Data Services Framework

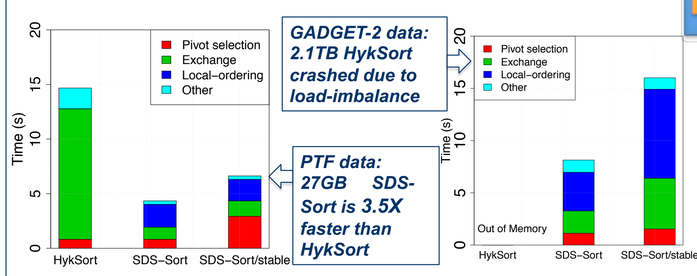
Integrate data management functions to support analyses:

❑Easy-to-use interface
- ➢ Based on familiar scientific data format standard: HDF5, …

❑More efficient data management
- ➢ Inherent parallel design
- ➢ Leverage massive investment in object store

❑Integrate storage and analysis capabilities
- ➢ High-performance data cloud: seamless distributed analyses





Array Data Model

➢ **Example task:** Join data from different sources is useful but time-consuming, e.g., comparing new and old astronomical observations to identify supernovae. Completing this step quickly is critical before the transients disappear.

➢ **Our Solution:**

✧Define a theoretical framework to identify optimal approaches [SIGMOD 2016]

✧Create incremental strategy to process periodic additions [SIGMOD 2017]

✧Design a distributed cache for query processing [SSDBM 2018]

➢ **Application:**

✧Help locate the past observations of two neutron stars in a collision (joint authorship in a Science paper).

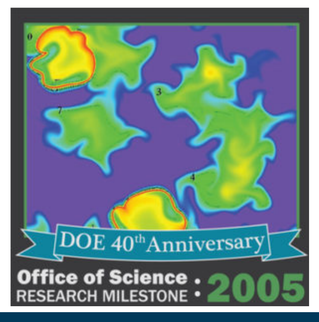
FastBit Indexing

FastBit is extremely efficient in many applications: high-energy physics, combustion, astrophysics, network security, drug discovery, …

The efficiency comes from new methods and algorithms, careful software engineering, and rigorous theoretical analyses to prove optimality

Won R&D 100 Award in 2008

Selected to be a part of the DOE40 celebration as a one of ASCR research milestones



ArrayUDF: Parallel Programming Model for Array Data

A novel scalable framework to perform user-defined custom data analysis on massive data on supercomputers

Significance and Impact

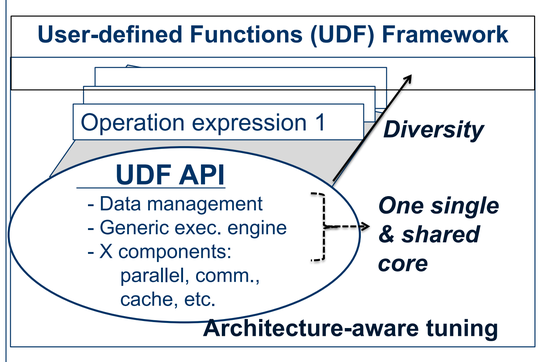
Tens to thousands of times faster than the state-of-the-art Big Data systems

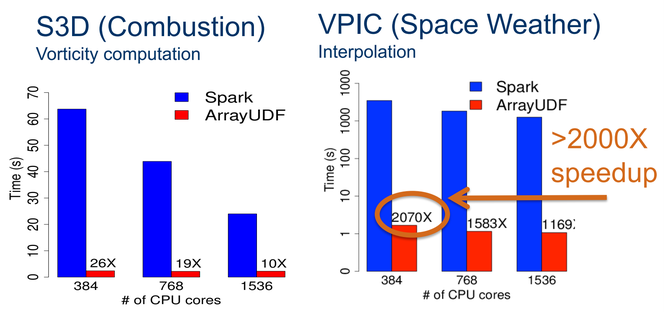
Research Details

–**Challenges**: Scientific data analyses require widely varying operations, typically as custom programs that repeat many common operations

–Existing Big Data systems focus on commercial data models (key-value, relational…), not suitable for scientific data in multi-dimensional arrays

–**Our solution**: An array-based, efficient, and scalable user-defined function (UDF) execution framework that allows users to define their operations on the familiar array data



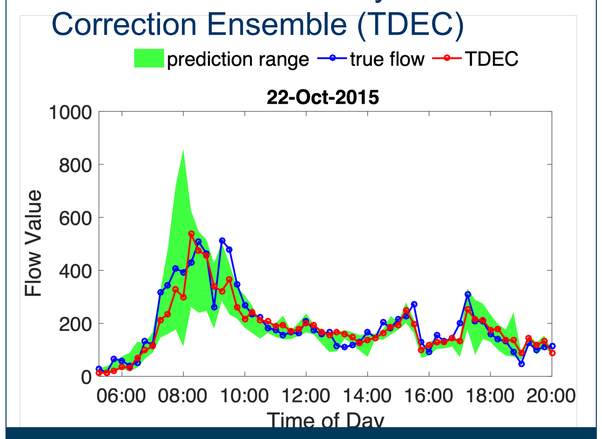


Streaming Data

Example Task: one-hour-ahead arterial traffic flow (#cars/hour) prediction in Arcadia, CA, at 15 min granularity (15 min/step)

Base models: (1) Autoregressive moving-average, (2) Partial Least Squares, (3) Support Vector Machine, (4) Kernel Ridge Regression, (5) Gaussian Process Regression

Our method: Time Decay Error-Correction Ensemble (TDEC)

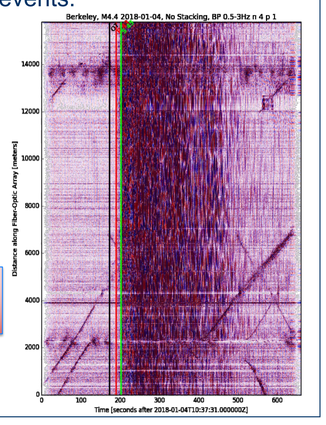


Applying Scientific Data Services to Distributed Acoustic Sensing Data

Distributed Acoustic Sensing (DAS) collects seismic data at high resolution, and requires high-performance analysis capability!

Detect different seismic events:
- earthquake
- vehicles
- ...

Much more sensors → Big data → Algorithm Needed → Better event detection



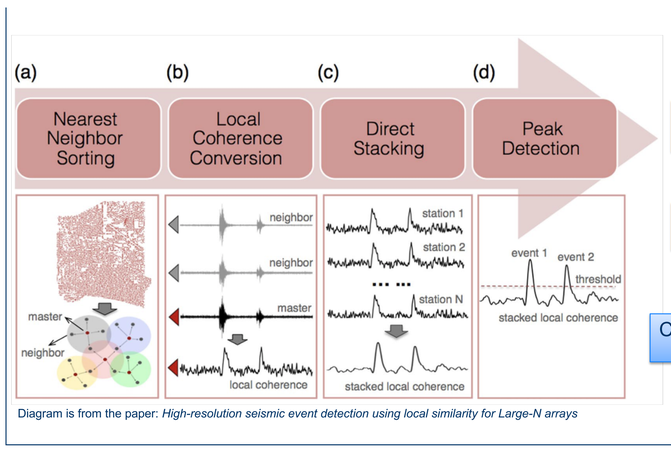


Diagram is from the paper: *High-resolution seismic event detection using local similarity for Large-N arrays*

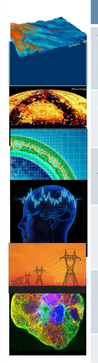
Matlab (perform with 12 workers) → **Many days**

Python (multithread with 64 threads) → **2 hours**

C++ with ArrayUDF (MPI with 500 processes) → **20 sec**

Additional Use Cases

Our technology significantly accelerates scientific applications

	Application	Approach	Size	Speed
	VPIC Plasmas	Block Index	100x	5x
	Cosmology	Block Index	100x	5x
	AMR	AMR-Index		500x
	Brain EEG	Statistical Similarity	106x	
	Power Grid	Statistical Similarity	198x	
	Mass Spec	Multilayout		90x

SDM

http://crd.lbl.gov/sdm

FastBit