

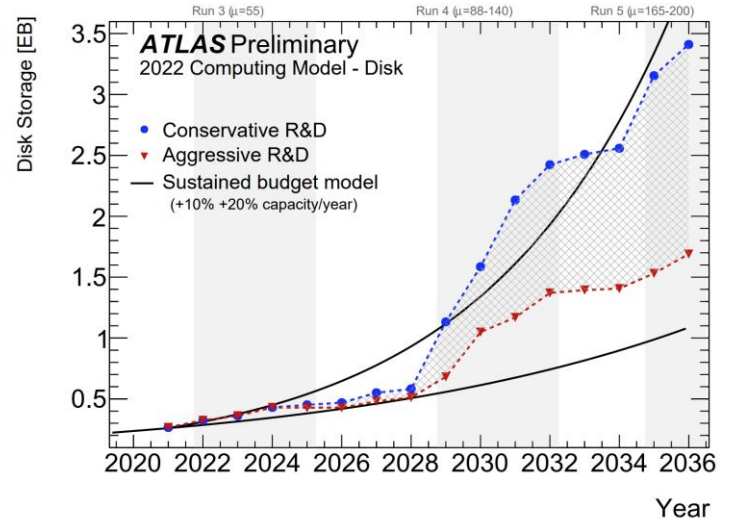
WE START WITH YES, DATA

HEP-CCE I/O STRATEGIES STORAGE & COMPRESSION OUTLOOK

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HEP-CCE/IOS: STORAGE AND COMPRESSION

Future Priorities

- The current cycle of HEP-CCE has been mainly focused on making HEP applications make [efficient] use of **High Performance Computer**
- This addresses the crucial need for **CPU cycles** expected for HEP experiment at the HL-LHC, DUNE and beyond.
- HEP, however, faces similar challenges for **disk and tape storage**, which also need to be addressed
 - Additional compute cycles may help, but won't solve this issue
- Most experiment HEP data is stored in a compressed format using **standard loss-less compression** algorithms
- More **advanced/intelligent**, but often **lossy compression** algorithms are less common
 - Exception: **CMS Nano-AOD**, soon? **ATLAS PHYSLITE**

INTELLIGENT LOSSY COMPRESSION

Computing Science

- Overview of "intelligent" data compression:
- Oct 18, 2022: **Speakers:** Prof. Anand Rangarajan , Prof. Sanjay Ranka:
Hybrid Learning Techniques for Scientific Data Reduction with Performance Guarantees
- Nov 29, 2022: **Speakers:** Dr Franck Cappello (ANL), Dr Sheng Di (ANL):
Compression of Scientific Data with SZ
- Mar 21, 2023: **Speaker:** John Wu (LBNL):
Statistical Similarity for Data Compression

HYBRID LEARNING TECHNIQUES FOR SCIENTIFIC DATA REDUCTION

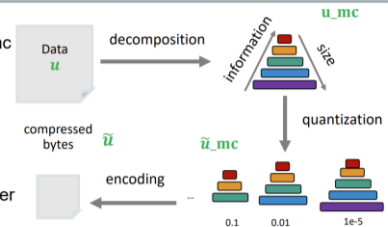
Prof. Anand Rangarajan , Prof. Sanjay Ranka: [GitHub - CODARcode/MGARD](#): **MGARD: MultiGrid Adaptive Reduction of Data**

- Compression of scientific applications differ from video and image compression
 - Guarantees on Quantities of Interest (QoI): Scientists are principally interested in QoI that are derived from raw data. The ability to quantify these with realistic bounds is essential.
- Compression Ratio of **~30-40** for fusion code data

MGARD – Multigrid Adaptive Recursive Decomposition

- MGARD is a transform-based compressor

- Decompose the original data u into u_mc by recursively performing L^2 projection and multilinear interpolation on the multilevel grids.
- Quantize u_mc to \tilde{u}_mc keeping error tolerance
- Encode \tilde{u}_mc to \tilde{u} to reduce the number of bits



- PD Guarantees: Method controls the compression error for a variety of s-norms. The relation between $\|u_mc - \tilde{u}_mc\|_s$ and $\|u - \tilde{u}\|_s$ is mathematically preserved
- QoI Guarantees: Provide error management on linearly derived QoI.
- **Compression ratios at PD error and QoI error within NRMSE 10^{-3} for XGC: 30-40.** Compression is smaller for lower QoI error bounds.

- Used for XGC Fusion Code that can produce 4.3 PB/day.

COMPRESSION OF SCIENTIFIC DATA WITH SZ

Dr Franck Cappello (ANL), Dr Sheng Di (ANL): SZ Lossy Compression | SZ Lossy Compressor (szcompressor.org)

- Consist in reducing scientific data volume by leveraging correlations and reducing precision
- Goal: keep the same science
 - Requires error bounds on observables
- Compression Ratio of **~5-100** for scientific data

Example: Cosmology 1/2 (Storage Footprint Reduction)

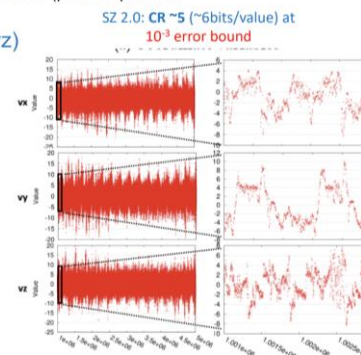
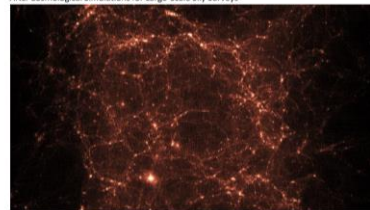
HACC: N-body problem with domain decomposition, medium/long-range force solver (particle-mesh method), short-range force solver (particle-particle/particle-mesh algorithm).

Particle dataset: 6 x 1D array (x, y, z, vx, vy, vz)

Preferred error controls:

- Point wise max error (Relative) bound
- Absolute (position), Relative (Velocity)

ANL: Cosmological Simulations for Large Scale Sky Surveys

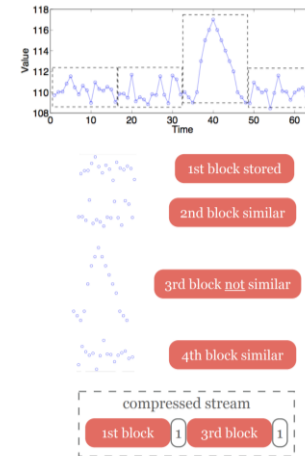


- An example application others understand better than me ;).

STATISTICAL SIMILARITY FOR DATA COMPRESSION

John Wu (LBNL): IDEALEM at LBNL (lbl.gov)

- Motivated by reading out many (1000s) of micro-Phaser Measurement Unit over time
 - Monitoring device is capable of sample dozens of measures many thousands of times a second
- That's for the power grid, don't ask me how, but does not sound so unsimilar to some detectors.
- Compression Ratio of ~100-200 in PMU example!



How IDEALEM Works

- Breaks an incoming data stream into blocks of a fixed size
 - Represents similar blocks with the one that appears earlier in the sequence
 - Similarity here is based on statistical measure
 - not on Euclidean distance
 - Kolmogorov-Smirnov test (KS test)
- One drawback/challenge: KS test is **computational expensive**.

OUTLOOK

- HEP-CCE/IOS has accomplished their main goals:
 - **Darshan for ROOT I/O** in HEP workflows on HPC
 - Investigate **HDF5 as intermediate event storage** for HPC processing using ROOT serialization
 - Start to Investigate **HPC/GPU friendly data model** (joined with PPS)
- Documentation (and CHEP publications) are being worked on and should be completed before project end.
- Foundation research for next HEP-CCE cycle work is well underway:
 - Investigate **HPC/GPU friendly data model** (joined with PPS)
 - Intelligent lossy **compression for storage** needs reduction
- Big Thanks to everyone involved, HEP-CCE and experiments!