# Zarr vs. HDF5

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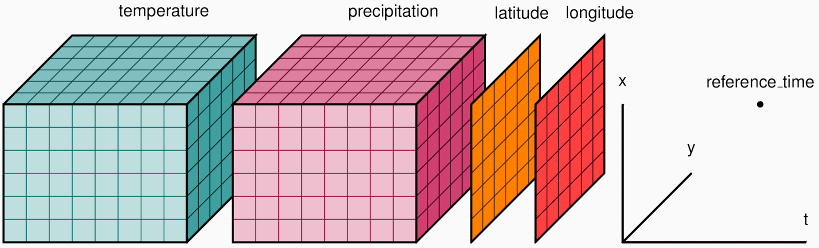
## Core Concepts

## Multidimensional Data



## Compression

same information in less space

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lossless

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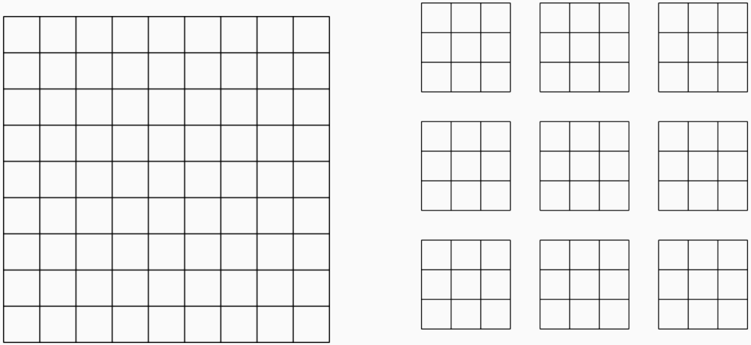
lossy

## Chunks



## Chunks

compression/random access trade off

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throughput/latency access trade off

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reduce io

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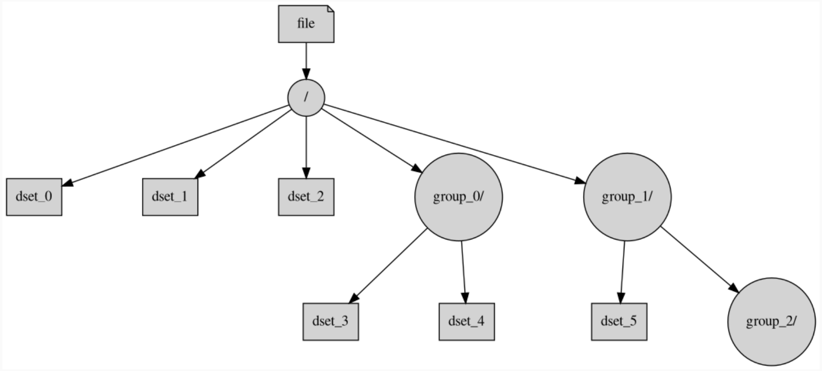
throughput/latency access trade off

reduce io

facilitate caching

## Hierarchy


file
/
dset_0
dset_1
dset_2
group_0/
group_1/
dset_3
dset_4
dset_5
group_2/

## Nodes

**Definition (Dataset)**

a multidimensional array

leaves of a Zarr or HDF5 tree

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**Definition (Node)**

either a **dataset** or **group**

## Attributes

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key-value data

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key-value data

property of each **node**

## Python Interface

## General

nested dictionaries

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leaves are *array-like*

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supports numpy-style indexing

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NOTE: describes `h5py`, not `pytables`

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>>> f['dset'][10, 3]
53
>>> f['dset'][:]
array([...]])
```

## h5py

```
>>> import h5py
>>> f = h5py.File('file.h5', 'r+')
>>> f
<HDF5 file "file.h5" (mode r+)>

>>> f['dset'] = np.arange(20 * 5).reshape(20, 5)
>>> f['dset']
<HDF5 dataset "dset": shape (20, 5), type "<i8">

>>> f['dset'][10, 3]
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>>> f['dset'][:]
array([...]])
```

## Extra Functionality

`Node.attrs` to get access to attributes as dict-like object

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`Group.create_dataset` to set chunk shape and compression

`Group.create_group` to create sub-groups

`Dataset.read_direct` to read into existing buffers

## Making a Decision

## HDF5

- over 20 years old

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## Extensions

filters and compressors

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ease of distributing extensions

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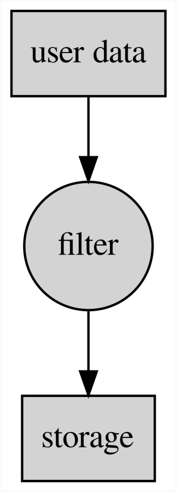
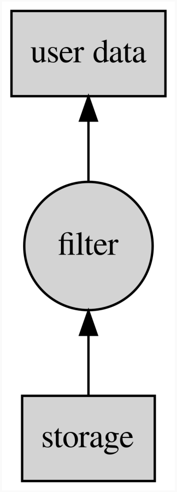
act on one chunk at a time

## Filters

**write**

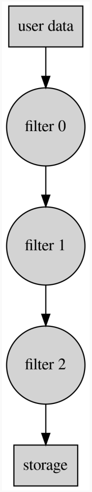


**read**



## Filter Pipelines

**write**



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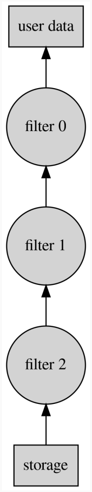

## Default Filters in HDF5

- `lzf`
- `gzip`
- `szip` (patent issues)
- `scale-offset` (lossy)
- `shuffle`
- `fletcher32` (checksum)

## Default Filters in Zarr

- blosc
- lz4
- zstd
- zlib
- gzip
- bz2
- lzma

- delta
- fixed_scale_offset
- quantize (lossy)
- pack_bits (boolean packing)
- categorical (str $\rightarrow$ int)
- json, msgpack, pickle
- vlen_string

## Writing an HDF5 Filter

```
static size_t
f(unsigned int flags,
  size_t cd_nelmts, const unsigned cd_values[],
  size_t nbytes, size_t *buf_size, void **buf) {













}
```

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static size_t
f(unsigned int flags,
  size_t cd_nelmts, const unsigned cd_values[],
  size_t nbytes, size_t *buf_size, void **buf) {
    if (!(flags & H5Z_FLAG_REVERSE)) {
        /* encode data */
    }
    else {
        /* decode data */
    }



}
```

## Writing an HDF5 Filter

```c
static size_t
f(unsigned int flags,
  size_t cd_nelmts, const unsigned cd_values[],
  size_t nbytes, size_t *buf_size, void **buf) {

    if (!(flags & H5Z_FLAG_REVERSE)) {
        /* encode data */
    }
    else {
        /* decode data */
    }

    return /* number of bytes in new buffer
              or 0 on failure */;

}
```

## Writing an HDF5 Filter Cont.

```c
static htri_t
can_apply(hid_t dcpl_id, hid_t type_id, hid_t space_id) {
    /* return -1 for error, 0 for false, or 1 for true */
}
```

## Writing an HDF5 Filter Cont.

```
const int my_filter_id = /* ... */;
static H5Z_class2_t filter = {
    .version = H5Z_CLASS_T_VERS,
    .id = my_filter_id,
    .encoder_present = 1,
    .decoder_present = 1,
    .name = "my_filter",
    .can_apply = can_apply,
    .set_local = NULL,
    .filter = f,
};

int my_filter_register() { return H5Zregister(&filter); }
```

## Using a Custom HDF5 Filter

```python
import ctypes
dll = ctypes.CDLL('filter.so')
assert dll.my_filter_register() == 0
filter_id = ctypes.c_int.in_dll(
    dll, 'my_filter_id',
).value
```

## Using a Custom HDF5 Filter

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    dll, 'my_filter_id',
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f = h5py.File('a.h5', 'r+')
dset = f.create_dataset(
    'dset',
    compression=filter_id,
    dtype='i8',
    shape=(100,),
)
```

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`h5py` statically links to `hdf5` by default

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must use `malloc`/`free`

can't use custom pipelines in `h5py` yet (I think)

doesn't trigger until flush

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filter ids use central authority

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filter ids use central authority

can be used in different languages

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filter ids use central authority

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plugin directory to find extension

## Writing a Zarr Filter

```
import numcodecs
from numcodecs.abc import Codec

class MyFilter(Codec):
    codec_id = 'my_filter'

    def encode(self, buf):
        ...

    def decode(self, buf, out=None):
        ...

numcodecs.register_codec(MyFilter)
```

## Using a Custom Zarr Filter

```python
import numpy as np
import zarr

from my_filter import MyFilter

f = zarr.open('a.zarr', 'w')
dset = f.create_dataset(
    'dset',
    compressor=MyFilter(),
    #filters=[..., MyFilter(), ...],
    dtype='i8',
    shape=(100,),
)
```

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split API is more clear

easily works in filter pipelines

## Delta of Deltas Example

`https://github.com/lllllllll/zarr-vs-hdf5-talk/blob/master/examples/delta_of_delta_filter`

## Storage

## Storage Protocol

abstract storage of structures

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metadata (tree structure, extra driver info)

## HDF5 Storage Model

virtual contiguous memory space

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allocator-like

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no information about semantic data

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library handles caching/locking

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single threaded

## Zarr Storage Model

based on `dict` from `str` to `bytes`

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- `sec2` (posix API)
- `windows` (Windows file API)
- `stdio` (buffered, C `stdio.h`)
- `core` (in memory)
- `family` (directory of blocks)
- `fileobj` (`h5py` only)

## Default Storage Backends in Zarr

- `MemoryStore`
- `DirectoryStore`
- `TempStore`
- `NestedDirectoryStore`
- `ZipStore` (single file)
- `DBMStore`
- `LMDBStore`
- `SQLiteStore`
- `MongoDBStore`
- `RedisStore`
- `ABSStore` (Azure Blob Storage)
- `LRUStoreCache`
- `ConsolidatedMetadataStore`
- `S3Map` (third party)

## Writing a Custom HDF5 File Driver

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herr_t (*write)(H5FD_t* file, H5FD_mem_t type,
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herr_t (*read)(H5FD_t* file, H5FD_mem_t type,
               hid_t dxpl, haddr_t addr,
               size_t size, void* buffer);

/* 28 more member functions and
   static member variables */
```

## Using a Custom HDF5 File Driver

```python
import h5py

from my_driver_as_extension_module import set_fapl

h5py.register_driver('my_driver', set_fapl)
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file = h5py.File(
    'path/to/pass/to/driver/open'
    'w',
    driver='my_driver',
    **extra_driver_kwargs,
)
```

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not many people have published file drivers

## Good Points with Custom HDF5 File Drivers

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can flatten or cut up the data to use different drivers

64 bit memory space always

## Writing a Custom Zarr Storage Backend

```python
from collections.abc import MutableMapping

class MyStorageBackend(MutableMapping):
    def __getitem__(self, key):
        ...

    def __setitem__(self, key, data):
        ...

    def __delitem__(self, key):
        ...

    # ... __iter__, __len__
```

## Problems with Custom Zarr Storage Backends

always need to copy on read

## Good Points with Custom Zarr Storage Backends

composable

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user defined caching, consolidation, etc.

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written in Python

## Conclusion

## Takeaways

**Zarr**

- lots of modern features
- actively developed
- responsive and helpful devs
- Python focused/specific*
- easier to prototype extensions

**HDF5**

- stable mature code
- cross language support
- very single threaded
- harder to write extensions

## Thank You

- https://github.com/llllllllll (10 lowercase L's)
- Example delta of deltas filter for both HDF5 and Zarr: https://github.com/llllllllll/zarr-vs-hdf5-talk/blob/master/examples/delta_of_delta_filter
- S3 file driver for HDF5: https://github.com/h5s3/h5s3
- @__qualname__