HDF5 Dynamically Loaded Filters

The HDF Group

This document describes the HDF5 dynamically loaded filter feature (HDF5 filter plugin) that will be released in the HDF5 version 1.8.11 in May 2013.

This feature allows an HDF5 application to apply a non-native HDF5 filter during I/O operations at run time. The application does not need to register the filter with the HDF5 library. There is no need for adding the filter to the HDF5 library and then linking the application with the modified library.

For example, the HDF5 1.8.11 command-line tools such as h5dump or h5ls downloaded from The HDF Group Website, or Java-based browsing tool HDFView that uses 1.8.11 will be able to read LZF or BZIP2 compressed datasets created by H5Py or PyTables software.

The dynamically loaded filter feature was sponsored by ***Deutsches Elektronen-Synchrotron (DESY)***, Hamburg, Germany.

1 Introduction

The HDF5 library provides an internal mechanism to compress an HDF5 dataset's raw data and the links stored in an HDF5 group object. Readers who are unfamiliar with HDF5 compression are encouraged to view the HDF5 Tutorials, the HDF5 User's Guide, the Reference Manual and other documentation available from the http://www.hdfgroup.org web site.

The HDF5 compression mechanism is a part of the HDF5 "filter pipeline" that modifies an application's data during the I/O operations. The pipeline was designed to be extensible. New filters could be easily added to the pipeline by an application or the HDF5 library code can be modified with a new filter to be later used by the application.

The HDF5 library supports several "internal" filters (see *HDF5 User's Guide*, section 5.4.2). Two filters, *deflate* and *szip*, depend on third-party compression libraries. All internal filters are configurable. They can be added or removed during the configuration step when the HDF5 library is built.

While currently available HDF5 "internal" compression methods work reasonably well on users' datasets, there are certain drawbacks to the current implementation. First, the "internal" compression methods may not provide the optimal compression ratio, as do some newly developed or specialized compression methods. Secondly, if a data provider wants to use a "non-internal" compression for storing the data in HDF5, he/she has to write a filter function that uses the new compression method and then register it with the library. Data consumers of such HDF5 files will need to have the new filter function and use it with their applications to read the data, or they will need a modified version of the HDF5 library that has the new filter as a part of the library.

If a user of such data doesn't have a modified HDF5 library installed on his system, command-line tools such as h5dump or h5ls will not be able to display the compressed data. Further more, it would be practically impossible to determine the compression method used, making the data stored in HDF5 useless.

It is clear that the current HDF5 filter mechanism, while extensible, doesn't work well with third-party filters. It would be a maintenance nightmare to keep adding and supporting new compression methods in HDF5. For any set of HDF5 "internal" filters, there always will be data with which the "internal" filters will not achieve the optimal performance needed to address data I/O and storage problems. Thus the current HDF5 filter mechanism should be enhanced to address the issues discussed above.

We have added a new feature to HDF5 called "dynamically loaded filters in HDF5." This feature will make the HDF5 third-party filters available to an application at run time. The third-party HDF5 filter function has to be a part of the HDF5 filter plugin installed on the system as a shared library or DLL.

To use a third-party filter an HDF5 application should call the `H5Pset_filter` function when setting the filter pipeline for a dataset creation property. The HDF5 library will register the filter with the library and the filter will be applied when data is written to the file.

When an application reads data compressed with a third-party HDF5 filter, the HDF5 library will search for the required filter plugin, register the filter with the library (if the filter function is not registered) and apply it to the data on the read operation.

This document describes this new feature and provides details in the following sections.

2 Requirements

Current design for the HDF5 dynamically loaded filters feature addresses the following requirements:

2.1 Functional requirements

1. There are **no changes to the HDF5 file format**.
2. There are **no changes to the HDF5 interface and the programming model** (see Section 3) in order to use the feature
3. The HDF5 third-party filters are available as **shared libraries or DLLs** on the user's system. The minimum content of the shared library satisfies the requirements as documented in Section 4.
4. There are predefined **default locations** where the HDF5 library searches the shared libraries or DLLs with the HDF5 filter functions.
5. The **default location may be overwritten** by an environment variable.
6. Once a filter plugin library is loaded, it stays loaded until the HDF5 library is closed.

Future enhancements:

- The default search locations can be specified in a configuration file.

2.2 Non-functional requirements

1. The HDF Group maintains a list of the third-party filters registered with HDF5 to facilitate tracking of a filter provenance. The current procedure is outlined at http://www.hdfgroup.org/services/contributions.html.
2. The HDF group publishes a specification and provides examples of dynamic loaded filters libraries.

Future enhancements:

- The HDF Group provides a repository such as SVN or GIT for the third-party filters and outlines a testing procedure that can be used by the filters maintainers to test the filters with the HDF5 libraries under development.

3 Programming model for applications

This section describes the programming model for an application that uses a third-party HDF5 filter plugin to write or read data. For simplicity of presentation it is assumed that the HDF5 filter plugin is available on the system in a default location. The HDF5 filter plugin is discussed in detail in Section 4.

3.1 Applying the third-party filter when creating and writing a dataset

The third-party filter can be added to the HDF5 filter pipeline by using the `H5Pset_filter` function, as a user would do in the past. The identification number and the filter parameters should be available to the application. For example, if the application intends to apply the HDF5 BZIP2 compression filter that was registered with The HDF Group and has an identification number 307 (see http://www.hdfgroup.org/services/contributions.html) then the application would follow the steps as outlines below:

```
dcpl = H5Pcreate (H5P_DATASET_CREATE);
status = H5Pset_filter (dcpl, (H5Z_filter_t)307, H5Z_FLAG_MANDATORY,
                        (size_t)6, cd_values);

dset = H5Dcreate (file, DATASET, H5T_STD_I32LE, space, H5P_DEFAULT, dcpl,
status = H5Dwrite (dset, H5T_NATIVE_INT, H5S_ALL, H5S_ALL, H5P_DEFAULT,
                   wdata[0]);
```

3.2 Reading data with the applied third-party filter

The application does not need to do anything special to read the data with the third-party filter applied. For example, if one wants to read data written in 3.1.1 the following regular steps should be taken:

```
file = H5Fopen (FILE, H5F_ACC_RDONLY, H5P_DEFAULT);
dset = H5Dopen (file, DATASET, H5P_DEFAULT);
       H5Dread (dset, H5T_NATIVE_INT, H5S_ALL, H5S_ALL, H5P_DEFAULT,
                rdata[0]);
```

Command-line utility h5dump, for example, will read and display the data as shown:

```
[epourmal@jam example]$ ./h5dump -p *.h5

HDF5 "h5ex_d_bzip2.h5" {

GROUP "/" {
   DATASET "DS1" {
      DATATYPE  H5T_STD_I32LE
      DATASPACE  SIMPLE { ( 32, 64 ) / ( 32, 64 ) }
      STORAGE_LAYOUT {
         CHUNKED ( 4, 8 )
         SIZE 6410 (1.278:1 COMPRESSION)
      }
      FILTERS {
         USER_DEFINED_FILTER {
            FILTER_ID 307
            COMMENT bzip2
            PARAMS { 6 }
         }
```

```
      }
      …
      }
      DATA {
      (0,0): 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14,
      (0,15): -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26,
      (0,27): -27, -28, -29, -30, -31, -32, -33, -34, -35, -36, -37, -38,
      (0,39): -39, -40, -41, -42, -43, -44, -45, -46, -47, -48, -49, -50,
      (0,51): -51, -52, -53, -54, -55, -56, -57, -58, -59, -60, -61, -62,
      (0,63): -63,
……
```

Compare with the result of h5dump version 1.8.10 and earlier:

```
[epourmal@jam example]$ h5dump -p *.h5
HDF5 "h5ex_d_bzip2.h5" {
GROUP "/" {
   DATASET "DS1" {
      DATATYPE  H5T_STD_I32LE
      DATASPACE  SIMPLE { ( 32, 64 ) / ( 32, 64 ) }
      STORAGE_LAYOUT {
         CHUNKED ( 4, 8 )
         SIZE 6410
      }
      FILTERS {
         UNKNOWN_FILTER {
            FILTER_ID 307
            COMMENT HDF5 bzip2 filter; see http://www.hdfgroup.org/services/contributions.html
            PARAMS { 6 }
         }
      }
      …
      }
      DATA {h5dump error: unable to print data

      }
   }
}
}
```

The complete example of writing and reading data with the applied third-party HDF5 filter is shown in Section 8. Please notice that the application DOES NOT need to link with the HDF5 plugin library.

3.3 A word of caution when using custom filters

Data goes through the HDF5 filter pipeline only when it is written to the file or read into application memory space from the file. For example, the I/O operation is triggered with a call to `H5Fflush`, or when a data item (HDF5 metadata or a raw data chunk) is evicted from cache or brought into cache. Please notice that H5Dread/write calls on the chunked datasets do not necessarily trigger I/O since the HDF5 library uses chunk cache.

A data item may remain in the cache until the HDF5 library is closed. If the HDF5 plugin that has to be applied to the data item becomes unavailable before the file and all objects in the file are closed, an

error will occur. The following example demonstrates the issue. Please notice the position of the H5Zunregister call:

```
    /*
     * Create a new group using compression.
     */
    gcpl = H5Pcreate (H5P_GROUP_CREATE);
    status = H5Pset_filter(gcpl,H5Z_FILTER_BZIP2,H5Z_FLAG_MANDATORY,(size_t)1, cd_values);
    group  = H5Gcreate (file, GNAME, H5P_DEFAULT, gcpl, H5P_DEFAULT);
    for (i=0; i < NGROUPS; i++) {
        sprintf(name, "group_%d", i);
        tmp_id = H5Gcreate (group, name, H5P_DEFAULT, H5P_DEFAULT, H5P_DEFAULT);
        status = H5Gclose(tmp_id);
    }

    status = H5Pclose (gcpl);
    status = H5Gclose (group);
    /*
     * Unregister the filter. Call to H5Fclose will fail because the library tries
     * to apply the filter that is not available anymore. This has a cascade effect
     * on H5Fclose.
     */
    H5Zunregister(H5Z_FILTER_BZIP2);
    status = H5Fclose (file);
```

Here is an error stack produced by the program:

```
HDF5-DIAG: Error detected in HDF5 (1.9.149) thread 0:
  #000: H5F.c line 2060 in H5Fclose(): decrementing file ID failed
    major: Object atom
    minor: Unable to close file
  #001: H5I.c line 1406 in H5I_dec_app_ref(): can't decrement ID ref count
    major: Object atom
    minor: Unable to decrement reference count
  #002: H5F.c line 1837 in H5F_close(): can't close file
    major: File accessibilty
    minor: Unable to close file
…….
  #026: H5Z.c line 1045 in H5Z_find(): required filter is not registered
    major: Data filters
    minor: Object not found
```

To avoid the problem make sure to close all objects to which the filter is applied and flush them using the H5Fflush call before unregistering the filter.

4 Programming model for HDF5 filter plugins

This section describes how to create an HDF5 filter, an HDF5 filter plugin, and how to install it on the system.

4.1 Writing a filter function

The HDF5 filter function for the dynamically loaded filter feature should be written as any custom filter described in http://www.hdfgroup.org/HDF5/doc/H5.user/Filters.html. See the example in Section 5 of that document to get an idea of the simple filter function and check the example of the more sophisticated HDF5 bzip2 filter function in Section **Error! Reference source not found.**. The HDF5 bzip2 filter function is also available for download from https://svn.hdfgroup.uiuc.edu/hdf5_plugins/trunk/BZIP2.

The user has to remember a few things when writing an HDF5 filter function.

1. An HDF5 filter is bidirectional.

   The filter handles both input and output to the file; a flag is passed to the filter to indicate the direction.

2. An HDF5 filter operates on a buffer.

   The filter reads data from a buffer, performs some sort of transformation on the data, places the result in the same or new buffer, and returns the buffer pointer and size to the caller.

3. An HDF5 filter should return zero in the case of failure.

The signature of the HDF5 filter function and the accompanying filter structure (see example in Section 4.2) are described in the *HDF5 Reference Manual* http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Z.html#Compression-Register.

4.2 Registering a filter with The HDF Group

If your are writing a filter that will be used by others, it would be a good idea to request a filter identification number and register it with The HDF Group. Please follow the procedure described at http://www.hdfgroup.org/services/contributions.html.

The HDF Group anticipates that developers of HDF5 filter plugins will not only register new filters, but also provide links to the source code and/or binaries for the corresponding HDF5 filter plugins.

It is very important for the users of the filter that you provide filter information in the “name” field of the filter structure, for example:

```
const H5Z_class2_t H5Z_BZIP2[1] = {
          H5Z_CLASS_T_VERS,       /* H5Z_class_t version */
         (H5Z_filter_t) 307,  /* Filter id number */
         1,                   /* encoder_present flag (set to true) */
         1,                   /* decoder_present flag (set to true) */
         "HDF5 bzip2 filter; see
          http://www.hdfgroup.org/services/contributions.html",
                              /* Filter info  */
          NULL,                          /* The "can apply" callback */
```

```
    NULL,                           /* The "set local" callback */
  (H5Z_func_t) H5Z_filter_bzip2,    /* The filter function */
};
```

The HDF5 library and command-line tools have access to the "name" field. An application can use the `H5Pget_filter<*>` functions to retrieve information about the filters.

Using the example of the structure above, the h5dump tool will print the string "`HDF5 bzip2 filter found at …`" pointing users to the applied filter (see example in Section 3.2) thus solving the problem of filter's origin.

4.3 Creating HDF5 filter plugin

The HDF5 filter plugin source should include:

1. The `H5PLextern.h` header file from the HDF5 distribution.
2. Definition of the filter structure (example shown in Section 4.2).
3. The filter function (for example, `H5Z_filter_bzip2`.)
4. Two functions necessary for the HDF5 library to find the correct type of the plugin library while loading it at run time and to get information about the filter function:

   ```
   H5PL_type_t   H5PLget_plugin_type(void);
   const void*   H5PLget_plugin_info(void);
   ```

   Here is an example of the functions above for the HDF5 bzip2 filter:

   ```
   H5PL_type_t   H5PLget_plugin_type(void) {return H5PL_TYPE_FILTER;}
   const void*   H5PLget_plugin_info(void) {return H5Z_BZIP2;}
   ```

5. It may also include other functions, for example, the source of the compression library.

Build the HDF5 filter plugin as a shared library. The following steps should be taken:

1. When compiling, point to the HDF5 header files.
2. Use the appropriate linking flags.
3. Link with any required external libraries.
4. For example, if `libbz2.so` is installed on a Linux system, the HDF5 `bzip2` plugin library `libH5Zbzip2.so` may be linked with `libbz2.so` instead of including `bzip2` source into the plugin library.

   The complete example of the HDF5 `bzip2` plugin library is provided at http://svn.hdfgroup.uiuc.edu/hdf5_plugins/trunk/BZIP2/ and can be adopted for other plugins. A simple Makefile file for Linux systems is shown in Section 10.

4.4 Installing HDF5 filter plugin

The default directory for an HDF5 filter plugin library is defined on UNIX-like systems as

"/usr/local/hdf5/lib/plugin" and on Windows systems as "%ALLUSERSPROFILE%/hdf5/lib/plugin".

The default path can be overwritten by a user with the HDF5_PLUGIN_PATH environment variable. Several directories can be specified for the search path using ":" as a path separator for UNIX-like systems and ";" for Windows.

Section 7 provides an example of the HDF5 bzip2 plugin that the reader is encouraged to try.

5 Design

Dynamic loading of the HDF5 filter plugin (or filter library) is triggered only by two events: when an application calls the H5Pset_filter function to set the filter for the first time, or when the data to which the filter is applied is read for the first time.

5.1 Data writing

This section outlines the usage of the new feature on the write operation.

When the application enables a filter with H5Pset_filter, the library will search for it by its filter identifier. The library will first search for the filter among its internal filters and custom filters registered with the library, then in the list of dynamically loaded filters that have been loaded in the library. If it cannot find the filter, it will search for the filter library in the default path or the path indicated by the environment variable HDF5_PLUGIN_PATH.

When found, the HDF5 library will load the filter library, register the filter, and add it to the filter pipeline. There is no need for application to register the dynamic filter with H5Zregister, as this step is done internally in H5Pset_filter. The H5PL_load function in the H5Pocpl.c file in the src directory of the HDF5 library distribution does the searching and loading the filter library.

Once the filter library is loaded, it will stay loaded until the HDF5 library is closed or until the filter is unregistered with the H5Zunregister call. The H5Zregister function is still required when a third-party filter is linked into an application and is not provided as a shared library.

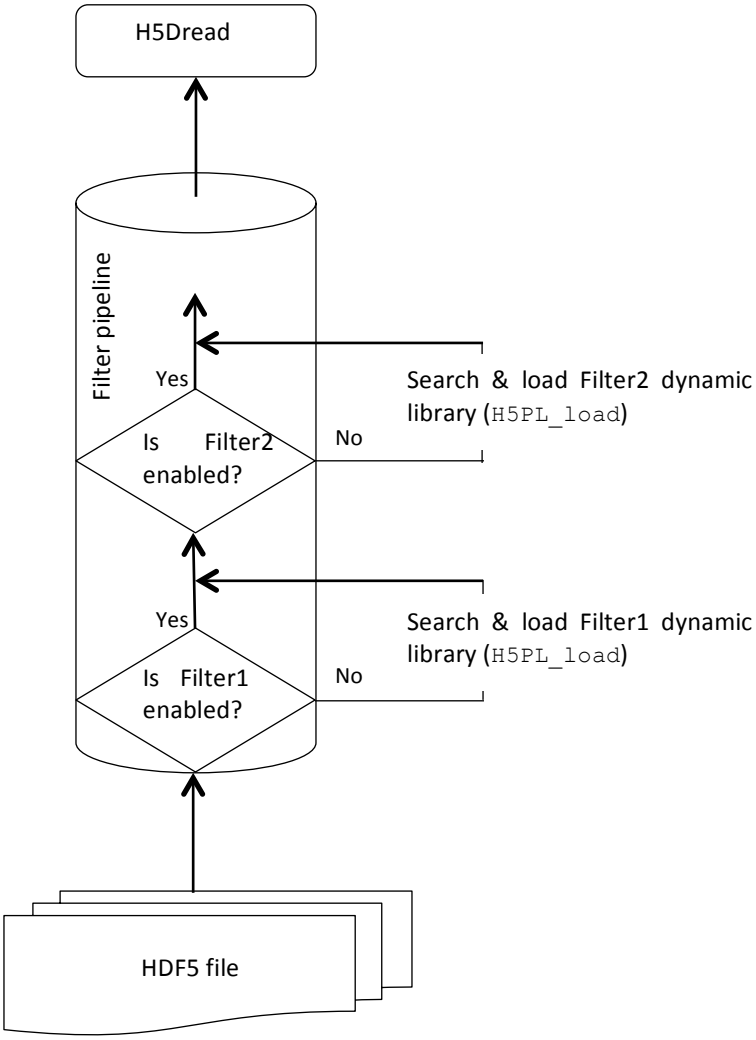
If the dynamic loaded filter has any auxiliary data, such as the compression level for BZIP2 filter, it can be passed in through the cd_values parameter of H5Pset_filter.

5.2 Data reading

This section outlines the usage of the new feature on the read operation.

At the application level, the user needs not do anything special. Inside the HDF5 library, when the library sees a filter identification value associated with a data item, it first searches the filter among its internal filters, then in the list of dynamically loaded filters that have been loaded in the library. If it cannot find the filter, it will search for and load the filter plugin library. Once the filter library is loaded, it will stay open until the HDF5 library is closed. Below is a simple diagram showing the design of the library.

Figure 1. Reading data with a dynamic loaded filter



The required changes were implemented in the H5Z_pipeline function that resides in the `H5Z.c` file in the `src` directory of the HDF5 library distribution.

5.3 New HDF5 source files for dynamically loaded filters

Three new source files were added to the HDF5 source code distribution under the `src` directory: `H5PLextern.h`, `H5PLprivate.h`, and `H5PL.c`. The `H5PL.c` file contains functions for managing plugins.

5.4 Testing dynamically loaded filters

The `plugin.c` file in the `test` directory contains a test for the feature. The test is controlled by the `test_plugin.sh.in` script in the same directory.

The HDF Group will use BZIP2 (and other plugins if they become available) to test the feature with the HDF5 libraries under development. For more on the BZIP2 plugin see Section 7.

6 Proposed changes to the HDF5 command-line tools

6.1 h5dump, h5ls and h5copy

Since reading the data is transparent to application including HDF5 command-line tools, these command line tools do not require any changes. A small improvement was done to the h5dump output to replace "UNKNOWN_FILTER" with "USER_DEFINED_FILTER".

6.2 h5repack

As in the case of the tools mentioned in Section 6.1, h5repack doesn't require any changes for reading a dataset with applied third-party filter.

To support application of a third-party filter while repacking a datasets, new syntax is needed to provide filter information to the tool: filter identification number, number of the filter parameters, and the values of the filter parameters. The proposed syntax to specify user defined filter an dits parameters is

```
h5repack –f  UD={ID:k; N:m; CD_VAL:[n1,…,nm]}…..
```

k is a filter identifier, m is a number of values in the CD_VAL array, and $n_{1,\ldots,}n_m$ are compression parameters. For example, to use BZIP2 compression with h5repack one would use

```
h5repack –f  UD={ID:307; N:1; CD_VAL:[9]} file1.h5 file2.h5
```

The enhancements to h5repack will be implemented in the HDF5 release 1.8.12.

7 Building HDF5 BZIP2 plugin example

The HDF Group provides an example of the HDF5 filter plugin that can be checked out from https://svn.hdfgroup.uiuc.edu/hdf5_plugins/trunk/BZIP2. It contains the source code for the `bzip2` plugin library and an example that uses the plugin. It requires the HDF5 library with the dynamically loaded feature and `bzip2` library being available on the system.

The plugin and the example can be built using `configure` or `CMake` commands. For instructions on how to build with `CMake` we refer the reader to the `README.txt` file in the source code distribution. The `bzip2` library that can be built with `CMake` is available from https://svn.hdfgroup.uiuc.edu/bzip2/.

Please follow the instructions below on how to build with `configure`.

1. Obtain, build and install the HDF5 library with the dynamically loaded filter feature.

   You may check the source from http://svn.hdfgroup.uiuc.edu/hdf5/branches/hdf5_1_8/ or download http://www.hdfgroup.uiuc.edu/ftp/pub/outgoing/hdf5/snapshots/v18/hdf5-1.8.11-snap16.tar.gz.

2. Make sure that libbz2.so* is installed on your system. On most UNIX-like systems it will be under `/usr/lib`.

3. Obtain the source code for plugin using SVN or FTP the source tar ball:

   `svn export` https://svn.hdfgroup.uiuc.edu/hdf5_plugins/trunk/BZIP2 `<plugin-dir>`

   ftp://ftp.hdfgroup.uiuc.edu/pub/outgoing/HDF5-plugins/BZIP2-plugin.tar.gz

4. You can build in place or using the "`srdir`" configure option. If you build in place as shown below, you will find the plugin under the `<plugin-dir>/plugins` directory.

```
cd <plugin-dir>
./configure –with-hdf5=<INSTALL-HDF5-DIR> --with-bz2lib=/usr
make
make check
make install
```

5. Setup environment variable `HDF5_PLUGIN_PATH` to point to the `<plugin-dir>/plugins` directory.

```
setenv HDF5_PLUGIN_PATH <plugin-dir>/plugins
```

6. Use `<INSTALL-HDF5-DIR>/bin/h5dump` with the `h5ex_d_bzip2.h5` file found under the `example` directory of the BZIP2 plugin distribution to get an output as shown in Section 3.2.

8 Example

This example shows how to write and read data compressed with the bzip2 compression.

```
 1/************************************************************
 2
 3  This example shows how to write data and read it from a dataset
 4  using bzip2 compression.
 5  bzip2 filter is not available in HDF5.
 6  The example uses a new feature available in HDF5 version 1.8.11
 7  to discover, load and register filters at run time.
 8
 9 ************************************************************/
10
11#include "hdf5.h"
12#include <stdio.h>
13#include <stdlib.h>
14
15#define FILE            "h5ex_d_bzip2.h5"
16#define DATASET         "DS1"
17#define DIM0            32
18#define DIM1            64
19#define CHUNK0          4
20#define CHUNK1          8
21
22int
23main (void)
24{
25    hid_t           file, space, dset, dcpl;    /* Handles */
26    herr_t          status;
27    H5Z_filter_t    filter_id = 0;
28    char            filter_name[80];
29    hsize_t         dims[2] = {DIM0, DIM1},
30                    chunk[2] = {CHUNK0, CHUNK1};
31    size_t          nelmts = 1;           /* number of elements in cd_values */
32    const unsigned  int cd_values[1] = {6};     /* bzip2 default level is 2 */
33    unsigned int    values_out[1] = {99};
34    unsigned int    flags;
35    htri_t          avail;
36    unsigned        filter_config;
37    int             wdata[DIM0][DIM1],          /* Write buffer */
38                    rdata[DIM0][DIM1],          /* Read buffer */
39                    max,
40                    i, j;
41
42    /*
43     * Initialize data.
44     */
45    for (i=0; i<DIM0; i++)
46        for (j=0; j<DIM1; j++)
47            wdata[i][j] = i * j - j;
48
49    /*
50     * Create a new file using the default properties.
```

```
51     */
52    file = H5Fcreate (FILE, H5F_ACC_TRUNC, H5P_DEFAULT, H5P_DEFAULT);
53
54    /*
55     * Create dataspace.  Setting maximum size to NULL sets the maximum
56     * size to be the current size.
57     */
58    space = H5Screate_simple (2, dims, NULL);
59
60    /*
61     * Create the dataset creation property list, add the bzip2
62     * compression filter and set the chunk size.
63     */
64    dcpl = H5Pcreate (H5P_DATASET_CREATE);
65    status = H5Pset_filter (dcpl, H5Z_FILTER_BZIP2, H5Z_FLAG_MANDATORY,
                              (size_t)6, cd_values);
66
67    /*
68     * Check that filter is registered with the library now.
69     * If it is registered, retrieve filter's configuration.
70     */
71     avail = H5Zfilter_avail(H5Z_FILTER_BZIP2);
72    if (avail) {
73        status = H5Zget_filter_info (H5Z_FILTER_BZIP2, &filter_config);
74        if ( (filter_config & H5Z_FILTER_CONFIG_ENCODE_ENABLED) &&
75                (filter_config & H5Z_FILTER_CONFIG_DECODE_ENABLED) )
76            printf ("bzip2 filter is available for encoding and decoding.\n");
77    }
78    status = H5Pset_chunk (dcpl, 2, chunk);
79
80    /*
81     * Create the dataset.
82     */
83    printf ("....Writing bzip2 compressed data ..............\n");
84    dset = H5Dcreate (file, DATASET, H5T_STD_I32LE, space, H5P_DEFAULT, dcpl,
85                      H5P_DEFAULT);
86
87    /*
88     * Write the data to the dataset.
89     */
90    status = H5Dwrite (dset, H5T_NATIVE_INT, H5S_ALL, H5S_ALL, H5P_DEFAULT,
91                       wdata[0]);
92
93    /*
94     * Close and release resources.
95     */
96    status = H5Pclose (dcpl);
97    status = H5Dclose (dset);
98    status = H5Sclose (space);
99    status = H5Fclose (file);
100   status - H5close();
101
102
```

```
   103     printf ("....Close the file and reopen for reading ........\n");
   104     /*
   105      * Now we begin the read section of this example.
   106      */
   107
   108     /*
   109      * Open file and dataset using the default properties.
   110      */
   111     file = H5Fopen (FILE, H5F_ACC_RDONLY, H5P_DEFAULT);
   112     dset = H5Dopen (file, DATASET, H5P_DEFAULT);
   113
   114     /*
   115      * Retrieve dataset creation property list.
   116      */
   117     dcpl = H5Dget_create_plist (dset);
   118
   119     /*
   120      * Retrieve and print the filter id, compression level and filter's name
for bzip2.
   121      */
   122     filter_id = H5Pget_filter2 (dcpl, (unsigned) 0, &flags, &nelmts,
                    values_out, sizeof(filter_name), filter_name, NULL);
   123     printf ("Filter info is available from the dataset creation property \n ");
   124     printf ("  Filter identifier is ");
   125     switch (filter_id) {
   126         case H5Z_FILTER_BZIP2:
   127             printf ("%d\n", filter_id);
   128             printf ("   Number of parameters is %d with the value %u\n",
                            nelmts, values_out[0]);
   129             printf ("   To find more about the filter check %s\n",
                            filter_name);
   130             break;
   131         default:
   132             printf ("Not expected filter\n");
   133             break;
   134     }
   135     /*
   136      * Check that filter is not registered with the library yet.
   137      */
   138      avail = H5Zfilter_avail(H5Z_FILTER_BZIP2);
   139     if (!avail)
   140         printf ("bzip2 filter is not yet available after the H5Pget_filter
                     call.\n");
   141     else
   142         return 1;
   143
   144
   145     /*
   146      * Read the data using the default properties.
   147      */
   148     printf ("....Reading bzip2 compressed data ..............\n");
   149     status = H5Dread (dset, H5T_NATIVE_INT, H5S_ALL, H5S_ALL, H5P_DEFAULT,
   150                 rdata[0]);
```

```
151
152     /*
153      * Find the maximum value in the dataset, to verify that it was
154      * read correctly.
155      */
156     max = rdata[0][0];
157     for (i=0; i<DIM0; i++)
158         for (j=0; j<DIM1; j++) {
159             /*printf("%d \n", rdata[i][j]); */
160             if (max < rdata[i][j])
161                 max = rdata[i][j];
162         }
163     /*
164      * Print the maximum value.
165      */
166     printf ("Maximum value in %s is %d\n", DATASET, max);
167     /*
168      * Check that filter is registered with the library now.
169      */
170     avail = H5Zfilter_avail(H5Z_FILTER_BZIP2);
171     if (avail)
172         printf ("bzip2 filter is available now since H5Dread triggered loading
                     of the filter.\n");
173
174
175     /*
176      * Close and release resources.
177      */
178     status = H5Pclose (dcpl);
179     status = H5Dclose (dset);
180     status = H5Fclose (file);
181
182     return 0;
183 }
```

9 HDF5 BZIP2 filter plugin

This section provides partial code for the BZIP2 filter plugin. For complete code check http://svn.hdfgroup.uiuc.edu/hdf5_plugins/trunk/BZIP2/src/H5Zbzip2.c

```
 1 /*
 2  * This file is an example of an HDF5 filter plugin.
 3  * The filter function  H5Z_filter_bzip2 was adopted from
 4  * PyTables http://www.pytables.org.
 5  * The plugin can be used with the HDF5 library vesrion 1.8.11 to read
 6  * HDF5 datasets compressed with bzip2 created by PyTables.
 7  */
 8
 9 /*
10  *
11 Copyright Notice and Statement for PyTables Software Library and Utilities:
12
…
45 */
46 #include <sys/types.h>
47 #include <stdlib.h>
48 #include <string.h>
49 #include <assert.h>
50 #include <stdio.h>
51 #include <H5PLextern.h>
52
53 #include <bzlib.h>
54
55 static size_t H5Z_filter_bzip2(unsigned int flags, size_t cd_nelmts,
56                       const unsigned int cd_values[], size_t nbytes,
57                       size_t *buf_size, void **buf);
58
59 /*
…
62  * See http://www.hdfgroup.org/services/contributions.html for more information.
63  *
64  * If you intend your plugin to be used by others, please register your filter
65  * with The HDF Group.
66  */
67 #define H5Z_FILTER_BZIP2 307
68
69 const H5Z_class2_t H5Z_BZIP2[1] = {{
70     H5Z_CLASS_T_VERS,       /* H5Z_class_t version */
71     (H5Z_filter_t)H5Z_FILTER_BZIP2,         /* Filter id number             */
72     1,              /* encoder_present flag (set to true) */
73     1,              /* decoder_present flag (set to true) */
74     "HDF5 bzip2 filter; see http://www.hdfgroup.org/services/contributions.html",
75                                 /* Filter name for debugging    */
76     NULL,                       /* The "can apply" callback     */
77     NULL,                       /* The "set local" callback     */
78     (H5Z_func_t)H5Z_filter_bzip2,         /* The actual filter function   */
79 }};
80
81 H5PL_type_t   H5PLget_plugin_type(void) {return H5PL_TYPE_FILTER;}
```

```
 82 const void *H5PLget_plugin_info(void) {return H5Z_BZIP2;}
 83
 84 static size_t H5Z_filter_bzip2(unsigned int flags, size_t cd_nelmts,
 85                       const unsigned int cd_values[], size_t nbytes,
 86                       size_t *buf_size, void **buf)
 87 {
 88   char *outbuf = NULL;
 89   size_t outbuflen, outdatalen;
 90   int ret;
 91
 92   if (flags & H5Z_FLAG_REVERSE) {
 93
 94     /** Decompress data.
 95      **
…
102      **/
103
104     bz_stream stream;
105     char *newbuf = NULL;
106     size_t newbuflen;
107
108     /* Prepare the output buffer. */
109     outbuflen = nbytes * 3 + 1;  /* average bzip2 compression ratio is 3:1 */
110     outbuf = malloc(outbuflen);
111     if (outbuf == NULL) {
112       fprintf(stderr, "memory allocation failed for bzip2 decompression\n");
113       goto cleanupAndFail;
114     }
115
116     /* Use standard malloc()/free() for internal memory handling. */
117     stream.bzalloc = NULL;
118     stream.bzfree = NULL;
119     stream.opaque = NULL;
120
121     /* Start decompression. */
122     ret = BZ2_bzDecompressInit(&stream, 0, 0);
123     if (ret != BZ_OK) {
124       fprintf(stderr, "bzip2 decompression start failed with error %d\n", ret);
125       goto cleanupAndFail;
126     }
127
128     /* Feed data to the decompression process and get decompressed data. */
129     stream.next_out = outbuf;
130     stream.avail_out = outbuflen;
131     stream.next_in = *buf;
132     stream.avail_in = nbytes;
133     do {
134       ret = BZ2_bzDecompress(&stream);
135       if (ret < 0) {
136        fprintf(stderr, "BUG: bzip2 decompression failed with error %d\n", ret);
137        goto cleanupAndFail;
138       }
139
140       if (ret != BZ_STREAM_END && stream.avail_out == 0) {
141         /* Grow the output buffer. */
142         newbuflen = outbuflen * 2;
```

```
143         newbuf = realloc(outbuf, newbuflen);
144         if (newbuf == NULL) {
145           fprintf(stderr, "memory allocation failed for bzip2 decompression\n");
146           goto cleanupAndFail;
147         }
148         stream.next_out = newbuf + outbuflen;  /* half the new buffer behind */
149         stream.avail_out = outbuflen;  /* half the new buffer ahead */
150         outbuf = newbuf;
151         outbuflen = newbuflen;
152       }
153     } while (ret != BZ_STREAM_END);
154
155     /* End compression. */
156     outdatalen = stream.total_out_lo32;
157     ret = BZ2_bzDecompressEnd(&stream);
158     if (ret != BZ_OK) {
159       fprintf(stderr, "bzip2 compression end failed with error %d\n", ret);
160       goto cleanupAndFail;
161     }
162
163   } else {
164
165     /** Compress data.
166      **
…
171      **/
172
173     unsigned int odatalen;  /* maybe not the same size as outdatalen */
174     int blockSize100k = 9;
175
176     /* Get compression block size if present. */
177     if (cd_nelmts > 0) {
178       blockSize100k = cd_values[0];
179       if (blockSize100k < 1 || blockSize100k > 9) {
180        fprintf(stderr, "invalid compression block size: %d\n", blockSize100k);
181        goto cleanupAndFail;
182       }
183     }
184
185     /* Prepare the output buffer. */
186     outbuflen = nbytes + nbytes / 100 + 600;  /* worst case (bzip2 docs) */
187     outbuf = malloc(outbuflen);
188     if (outbuf == NULL) {
189       fprintf(stderr, "memory allocation failed for bzip2 compression\n");
190       goto cleanupAndFail;
191     }
192
193     /* Compress data. */
194     odatalen = outbuflen;
195     ret = BZ2_bzBuffToBuffCompress(outbuf, &odatalen, *buf, nbytes,
196                                    blockSize100k, 0, 0);
197     outdatalen = odatalen;
198     if (ret != BZ_OK) {
199       fprintf(stderr, "bzip2 compression failed with error %d\n", ret);
200       goto cleanupAndFail;
201     }
```

```
202   }
203
204   /* Always replace the input buffer with the output buffer. */
205   free(*buf);
206   *buf = outbuf;
207   *buf_size = outbuflen;
208   return outdatalen;
209
210  cleanupAndFail:
211   if (outbuf)
212     free(outbuf);
213   return 0;
214 }
```

10 Example of Makefile

This is an example for `Makefile`. Building shared libraries may be tricky. Please consult system documentation for the flags on your system. You may also want to consider using `libtool` as we don in the BZIP2 plugin example.

```
 1   CFLAGS = -fPIC -g
 2   CC = gcc
 3   HDF5_INSTALL = /mnt/scr1/_tmp/_build/hdf5/
 4   BZIP2_INSTALL = /mnt/scr1/bzip2-1.0.5
 5   MAJOR = 0
 6   MINOR = 1
 7   NAME1 = H5Zbzip2
 8   VERSION = $(MAJOR).$(MINOR)
 9
10   # Include files in hdf5/src build/src directories for hdf5.h and
         H5pubconf.h
11   INCLUDES = -I./ -I$(HDF5_INSTALL)/include -I$(BZIP2_INSTALL)
12
13   lib: lib$(NAME1).so.$(VERSION)
14
15   $(NAME1).o: $(NAME1).c
16         $(CC) $(CFLAGS) $(INCLUDES) -c $(NAME1).c
17
18   lib$(NAME1).so.$(VERSION): $(NAME1).o
19         $(CC) -shared -Wl,-soname,lib$(NAME1).so.$(MAJOR) $^ -o $@ -
L/$(BZIP2_INSTALL) -lbz2
20
21   clean:
22         $(RM) *.o *.so*
23
24   distclean:
25         $(RM) *.o *.so*
```

Revision History

March 31, 2013	Version 1 shared with developers who worked on the project.
April 9, 2013	Version 2 shared with The HDF Group developers.

References

1. The HDF Group. “HDF5 Documentation,” http://www.hdfgroup.org/HDF5/doc/doc-info.html (November 15, 2012).