Parallel File I/O with MPI-2

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Acknowledgements

This course is based on the MPI-I/O chapter of the MPI-2 tutorial on the MPIDC 2000:

MPI-2: Extensions to the Message Passing Interface

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Motivation, I.

- Many parallel applications need
  - coordinated parallel access to a file by a group of processes
  - simultaneous access
  - all processes may read/write many (small) non-contiguous pieces of the file,
    i.e. the data may be distributed amongst the processes according to a partitioning scheme
  - all processes may read the same data
- Efficient collective I/O based on
  - fast physical I/O by several processors, e.g. striped
  - distributing (small) pieces by fast message passing

Motivation, II.

- Analogy: writing / reading a file is like sending/receiving a message
- Handling parallel I/O needs
  - handling groups of processes -> MPI topologies and groups
  - collective operations -> file handle defined like communicators
  - non-blocking operations to overlap computation & I/O -> MPI_I..., MPI_Wait, ... & new **split** collective interface
  - non-contiguous access -> MPI derived datatypes

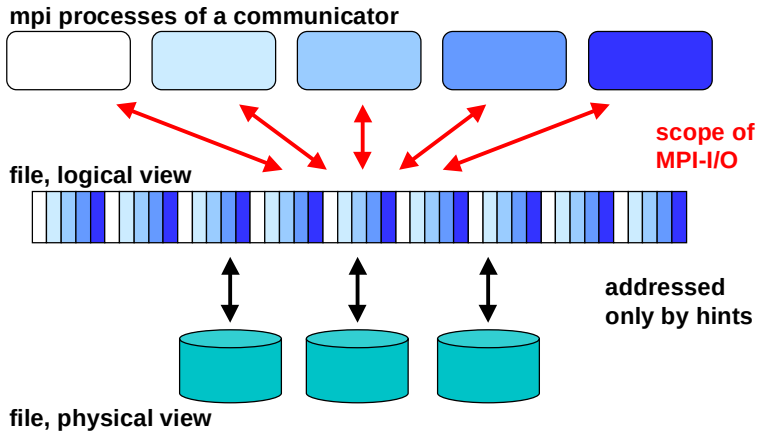
MPI-I/O Features

- Provides a high-level interface to support
  - data file partitioning among processes
  - transfer global data between memory and files (collective I/O)
  - asynchronous transfers
  - strided access
- MPI derived datatypes used to specify common data access patterns for maximum flexibility and expressiveness

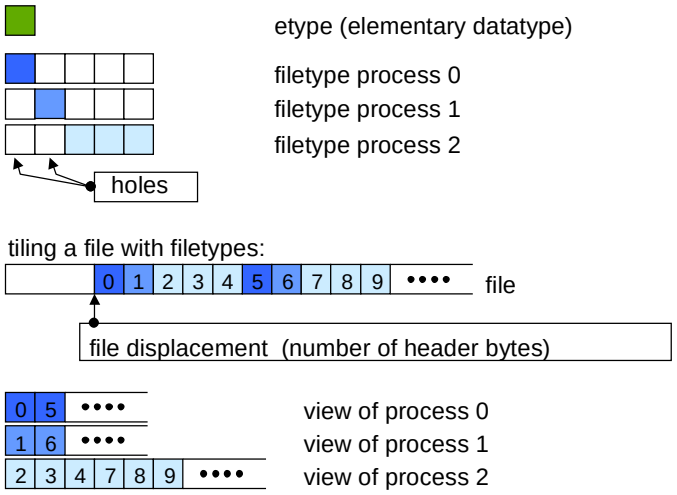
MPI-I/O, Principles

- MPI file contains elements of a single MPI datatype (etype)
- partitioning the file among processes with an access template (filetype)
- all file accesses transfer to/from a contiguous or non-contiguous user buffer (MPI datatype)
- non-blocking / blocking and collective / individual read / write routines
- individual and shared file pointers, explicit offsets
- automatic data conversion in heterog. systems
- file interoperability with external representation

Logical view / Physical view



Definitions



Comments on Definitions

file - an ordered collection of typed data items

etypes
- is the unit of data access and positioning / offsets
- can be any basic or derived datatype
  (with non-negative, monotonically non-decreasing, non-absolute displacem.)
- generally contiguous, but need not be
- typically same at all processes

filetypes
- the basis for partitioning a file among processes
- defines a template for accessing the file
- different at each process
- the etype or derived from etype (displacements: non-negative, monoton. non-decreasing, non-abs., multiples of etype extent)

view
- each process has its own view, defined by: a displacement, an etype, and a filetype.
- The filetype is repeated, starting at **displacement**

offset - position relative to current view, in units of etype

Opening an MPI File

- MPI_FILE_OPEN is collective over **comm**
- filename's namespace is implementation-dependent!
- filename must reference the same file on all processes
- process-local files can be opened by passing MPI_COMM_SELF as **comm**
- returns a file handle *fh*
  [*represents the file and the process group of* **comm**]

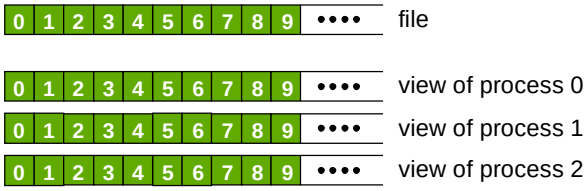
MPI_FILE_OPEN(comm, filename, amode, info, *fh*)

Default View

MPI_FILE_OPEN(comm, filename, amode, info, *fh*)

- Default:
  - displacement = 0
  - etype = MPI_BYTE
  - filetype = MPI_BYTE

  } each process has access to the whole file



- MPI_BYTE matches with any datatype

Access Modes

- same value of **amode** on all processes in MPI_FILE_OPEN
- Bit vector OR of integer constants (Fortran 77: +)
  - MPI_MODE_RDONLY - read only
  - MPI_MODE_RDWR - reading and writing
  - MPI_MODE_WRONLY - write only
  - MPI_MODE_CREATE - create if file doesn't exist
  - MPI_MODE_EXCL - error creating a file that exists
  - MPI_MODE_DELETE_ON_CLOSE - delete on close
  - MPI_MODE_UNIQUE_OPEN - file not opened concurrently
  - MPI_MODE_SEQUENTIAL - file only accessed sequentially: mandatory for sequential stream files (pipes, tapes, ...)
  - MPI_MODE_APPEND - all file pointers set to end of file [*caution: reset to zero by any subsequent MPI_FILE_SET_VIEW*]

File Info: Reserved Hints

- Argument in MPI_FILE_OPEN, MPI_FILE_SET_VIEW, MPI_FILE_SET_INFO
- reserved key values:
  - collective buffering
    - **"collective_buffering": specifies whether the application may benefit from collective buffering**
    - **"cb_block_size": data access in chunks of this size**
    - **"cb_buffer_size": on each node, usually a multiple of block size**
    - **"cb_nodes": number of nodes used for collective buffering**
  - disk striping (only relevant in MPI_FILE_OPEN)
    - **"striping_factor": number of I/O devices used for striping**
    - **"striping_unit": length of a chunk on a device (in bytes)**
- MPI_INFO_NULL may be passed

Closing and Deleting a File

- Close: collective

```
MPI_FILE_CLOSE(fh)
```

- Delete:
  - automatically by MPI_FILE_CLOSE
    if **`amode=MPI_DELETE_ON_CLOSE | ...`**
    was specified in MPI_FILE_OPEN
  - deleting a file that is not currently opened:

```
MPI_FILE_DELETE(filename, info)
```

[*same implementation-dependent rules as in MPI_FILE_OPEN*]

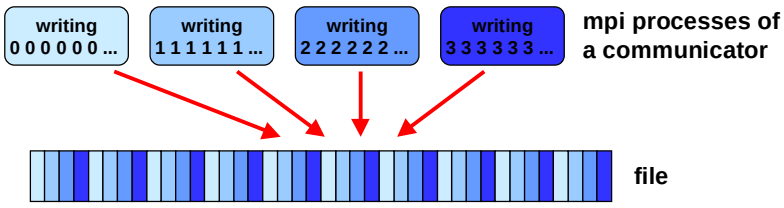
Writing with Explicit Offsets

MPI_FILE_WRITE_AT(fh,offset,buf,count,datatype,*status*)

- writes **`count`** elements of **`datatype`** from memory **`buf`** to the file
- starting **`offset`** * units of **`etype`**
  from begin of view (= **`displacement`**)
- the elements are stored into the locations of the current view
- the sequence of basic datatypes of **`datatype`**
  (= signature of **`datatype`**)
  must match
  contiguous copies of the **`etype`** of the current view

MPI–IO Exercise 1: Four processes write a file in parallel

- each process should write its rank (as one character) ten times
  to the offsets = my_rank + i * size_of_MPI_COMM_WORLD, i=0..9
- Result: “0123012301230123012301230123012301230123“
- Each process uses the default view



- please, use skeleton:
  cp ~/MPI/course/**C**/mpi_io/mpi_io_exa1_skel.c **my_exa1.c**
  cp ~/MPI/course/**F**/mpi_io/mpi_io_exa1_skel.f **my_exa1.f**

File Views

- Provides a set of data visible and accessible from an open file
- A separate view of the file is seen by each process through triple := (displacement, etype, filetype)
- User can change a view during the execution of the program - but collective operation
- A linear byte stream, represented by the triple (0, MPI_BYTE, MPI_BYTE), is the default view

Set/Get File View

- Set view
  - changes the process's view of the data
  - local and shared file pointers are reset to zero
  - collective operation
  - etype and filetype must be committed
  - datarep argument is a string that specifies the format in which data is written to a file: "native", "internal", "external32", or user-defined
  - same etype extent and same datarep on all processes
- Get view
  - returns the process's view of the data

MPI_FILE_SET_VIEW(fh, disp, etype, filetype, datarep, info)

MPI_FILE_GET_VIEW(fh, disp, etype, filetype, datarep)

Data Representation, I.

- "native"
  - data stored in file identical to memory
  - on homogeneous systems no loss in precision or I/O performance due to type conversions
  - on heterogeneous systems loss of interoperability
  - no guarantee that MPI files accessible from C/Fortran
- "internal"
  - data stored in implementation specific format
  - can be used with homogeneous or heterogeneous environments
  - implementation will perform type conversions if necessary
  - no guarantee that MPI files accessible from C/Fortran

Data Representation, II.

- "external32"
  - follows standardized representation (IEEE)
  - all input/output operations are converted from/to the "external32" representation
  - files can be exported/imported between different MPI environments
  - due to type conversions from (to) native to (from) "external32" data precision and I/O performance may be lost
  - "internal" may be implemented as equal to "external32"
  - can be read/written also by non-MPI programs
- user-defined

Fileview examples

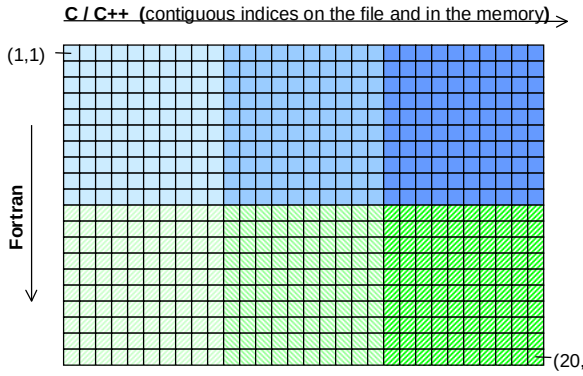
- Task
  - reading a global matrix from a file
  - storing a subarray into a local array on each process
  - according to a given distribution scheme

Example with Subarray, I.

- 2-dimensional distribution scheme: (BLOCK,BLOCK)
- garray on the file 20x30:
  - Contiguous indices is language dependent:
  - in Fortran: (1,1), (2,1), (3,1), ... , (1,10), (2,20), (3,10), ..., (20,30)
  - in C/C++: [0][0], [0][1], [0][2], ... , [10][0], [10][1], [10][2], ..., [19][29]
- larray = local array in each MPI process
  = subarray of the global array
- same ordering on file (garray) and in memory (larray)

Example with Subarray, II. — Distribution

- Process topology: 2x3
- global array on the file: 20x30
- distributed on local arrays in each processor: 10x10



Example with Subarray, III. — Reading the file

```
!!!! real garray(20,30)                                  ! these HPF-like comment lines !
!!!! PROCESSORS   procs(2,  3)                           ! explain the data distribution !
!!!! DISTRIBUTE garray(BLOCK,BLOCK) onto procs           ! used in this MPI program !
     real larray(10,10) ; integer (kind=MPI_OFFSET_KIND) disp,offset; disp=0; offset=0

     ndims=2 ; psizes(1)=2 ; period(1)=.false. ; psizes(2)=3 ; period(2)=.false.
     call MPI_CART_CREATE(MPI_COMM_WORLD, ndims, psizes, period,
                                                          .TRUE., comm, ierror)
     call MPI_COMM_RANK(comm, rank, ierror)
     call MPI_CART_COORDS(comm, rank, ndims, coords, ierror)

     gsizes(1)=20 ;  lsizes(1)= 10 ;  starts(1)=coords(1)*lsizes(1)
     gsizes(2)=30 ;  lsizes(2)= 10 ;  starts(2)=coords(2)*lsizes(2)
     call MPI_TYPE_CREATE_SUBARRAY(ndims, gsizes, lsizes, starts,
                        MPI_ORDER_FORTRAN, MPI_REAL, subarray_type, ierror)
     call MPI_TYPE_COMMIT(subarray_type , ierror)

     call MPI_FILE_OPEN(comm, 'exa_subarray_testfile', MPI_MODE_CREATE +
                        MPI_MODE_RDWR, MPI_INFO_NULL, fh, ierror)
     call MPI_FILE_SET_VIEW (fh, disp, MPI_REAL, subarray_type, 'native',
                        MPI_INFO_NULL, ierror)
     call MPI_FILE_READ_AT_ALL(fh, offset, larray, lsizes(1)*lsizes(2), MPI_REAL,
                        status, ierror)
```

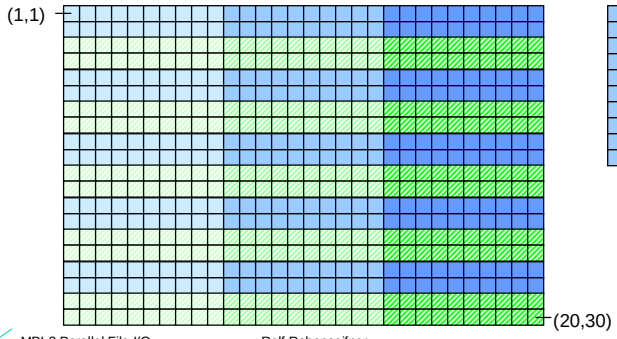
Example with Subarray, IV.

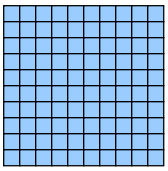
- All MPI coordinates and indices start with 0, even in Fortran, i.e. with MPI_ORDER_FORTRAN
- MPI indices (here **`starts`**) may differ (✓) from Fortran indices
- Block distribution on 2*3 processes:

rank = 0 coords = (0, 0) starts = (0, 0) garray(1:10, 1:10) = larray (1:10, 1:10)	rank = 1 coords = (0, 1) starts = (0, 10) garray(1:10, 11:20) = larray (1:10, 1:10)	rank = 2 coords = (0, 2) starts = (0, 20) garray(1:10, 21:30) = larray (1:10, 1:10)
rank = 3 coords = (1, 0) starts = (10, 0) garray(11:20, 1:10) = larray (1:10, 1:10)	rank = 4 coords = (1, 1) starts = (10, 10) garray(11:20, 11:20) = larray (1:10, 1:10)	rank = 5 coords = (1, 2) starts = (10, 20) garray(11:20, 21:30) = larray (1:10, 1:10)

Example with Darray, I.

- Distribution scheme: (CYCLIC(2), BLOCK)
- Cyclic distribution in first dimension with strips of length 2
- Block distribution in second dimension
- distribution of global garray onto the larray in each of the 2x3 processes
- garray on the file:
- e.g., larray on process (0,1):





Example with Darray, II.

```
!!!!  real garray(20,30)                                  ! these HPF-like comment lines !
!!!!  PROCESSORS   procs(2,  3)                           !     explain the data distribution!
!!!!  DISTRIBUTE garray(CYCLIC(2),BLOCK) onto procs  !used in this MPI program!
      real larray(10,10); integer (kind=MPI_OFFSET_KIND) disp, offset; disp=0; offset=0

      call MPI_COMM_SIZE(comm, size, ierror)
      ndims=2 ; psizes(1)=2 ; period(1)=.false. ; psizes(2)=3 ; period(2)=.false.
      call MPI_CART_CREATE(MPI_COMM_WORLD, ndims, psizes, period,
                                                          .TRUE., comm, ierror)
      call MPI_COMM_RANK(comm, rank, ierror)
      call MPI_CART_COORDS(comm, rank, ndims, coords, ierror)

      gsizes(1)=20 ;  distribs(1)= MPI_DISTRIBUTE_CYCLIC;  dargs(1)=2
      gsizes(2)=30 ;  distribs(2)= MPI_DISTRIBUTE_BLOCK;   dargs(2)=
                                                  MPI_DISTRIBUTE_DFLT_DARG
      call MPI_TYPE_CREATE_DARRAY(size, rank, ndims, gsizes, distribs, dargs,
                psizes, MPI_ORDER_FORTRAN, MPI_REAL, darray_type, ierror)
      call MPI_TYPE_COMMIT(darray_type , ierror)

      call MPI_FILE_OPEN(comm, 'exa_subarray_testfile', MPI_MODE_CREATE +
                          MPI_MODE_RDWR, MPI_INFO_NULL, fh, ierror)
      call MPI_FILE_SET_VIEW (fh, disp, MPI_REAL, darray_type, 'native',
                                  MPI_INFO_NULL, ierror)
      call MPI_FILE_READ_AT_ALL(fh, offset, larray, 10*10, MPI_REAL, istatus,
      ierror)
```


Example with Darray, III.

- Cyclic distribution in first dimension with strips of length 2
- Block distribution in second dimension
- Processes' tasks:

rank = 0 coords = (0, 0) garray([1: 2, 5: 6, 9:10, 13:14, 17:18], 1:10) = larray (1:10, 1:10)	rank = 1 coords = (0, 1) garray([1: 2, 5: 6, 9:10, 13:14, 17:18], 11:20) = larray (1:10, 1:10)	rank = 2 coords = (0, 2) garray([1: 2, 5: 6, 9:10, 13:14, 17:18], 21:30) = larray (1:10, 1:10)
rank = 3 coords = (1, 0) garray([3: 4, 7: 8, 11:12, 15:16, 19:20], 1:10) = larray (1:10, 1:10)	rank = 4 coords = (1, 1) garray([3: 4, 7: 8, 11:12, 15:16, 19:20], 11:20) = larray (1:10, 1:10)	rank = 5 coords = (1, 2) garray([3: 4, 7: 8, 11:12, 15:16, 19:20], 21:30) = larray (1:10, 1:10)

5 Aspects of Data Access

- Direction: Read / Write
- Positioning [realized via routine names]
  - explicit offset (_AT)
  - individual file pointer (no positional qualifier)
  - shared file pointer (_SHARED or _ORDERED)
    (different names used depending on whether non-collective or collective)
- Coordination
  - non-collective
  - collective (_ALL)
- Synchronism
  - blocking
  - non-blocking (I) and split collective (_BEGIN, _END)
- Atomicity, [realized with a separate API: MPI_File_set_atomicity]
  - non-atomic (default)
  - atomic: to achieve sequential consistency for conflicting accesses on same fh in different processes

All Data Access Routines

Positioning	Synchronization	Non-collective	Collective
Explicit offsets	blocking	READ_AT WRITE_AT	READ_AT_ALL WRITE_AT_ALL
	non-blocking & split collective	IREAD_AT IWRITE_AT	READ_AT_ALL_BEGIN READ_AT_ALL_END WRITE_AT_ALL_BEGIN WRITE_AT_ALL_END
Individual file pointers	blocking	READ WRITE	READ_ALL WRITE_ALL
	non-blocking & split collective	IREAD IWRITE	READ_ALL_BEGIN READ_ALL_END WRITE_ALL_BEGIN WRITE_ALL_END
Shared file pointers	blocking	READ_SHARED WRITE_SHARED	READ_ORDERED WRITE_ORDERED
	non-blocking & split collective	IREAD_SHARED IWRITE_SHARED	READ_ORDERED_BEGIN READ_ORDERED_END WRITE_ORDERED_BEGIN WRITE_ORDERED_END

Read e.g. **MPI_FILE**_READ_AT

Explicit Offsets

e.g. MPI_FILE_READ_AT(fh,offset,*buf*,count,datatype,*status*)

- attempts to read **`count`** elements of **`datatype`**
- starting **`offset`** **`*`** units of **`etype`**
  from begin of view (= **`displacement`**)
- the sequence of basic datatypes of **`datatype`**
  (= signature of **`datatype`**)
  must match
  contiguous copies of the **`etype`** of the current view
- EOF can be detected by noting that the amount of data read is less than **`count`**
  - i.e. EOF is no error!
  - use MPI_GET_COUNT(status,datatype,*recv_count*)

Individual File Pointer, I.

e.g. MPI_FILE_READ(fh, *buf*,count,datatype,*status*)

- same as *"Explicit Offsets"*, except:
- the offset is the current value of the
  individual file pointer of the calling process
- the individual file pointer is updated by

$$\text{new\_fp} = \text{old\_fp} + \frac{\text{elements(datatype)}}{\text{elements(etype)}} * \text{count}$$

  i.e. it points to the next etype after the last one that will be accessed
  (*formula is not valid if EOF is reached*)

Individual File Pointer, II.

MPI_FILE_SEEK(fh, offset, whence)

- set individual file pointer fp:
  - set fp to offset – if whence=MPI_SEEK_SET
  - advance fp by offset – if whence=MPI_SEEK_CUR
  - set fp to EOF+offset – if whence=MPI_SEEK_EOF

MPI_FILE_GET_POSITION(fh, *offset*)

MPI_FILE_GET_BYTE_OFFSET(fh, offset, disp)

- to inquire offset
- to convert offset into byte displacement
  [*e.g. for* ***disp*** *argument in a new view*]

MPI–IO Exercise 2: Using fileviews and individual filepointers

- Copy to your local directory:
  cp ~/MPI/course/**C**/mpi_io/mpi_io_exa2_skel.c **my_exa2.c**
  cp ~/MPI/course/**F**/mpi_io/mpi_io_exa2_skel.f **my_exa2.f**
- Tasks:
  - Each MPI-process of `my_exa2` should write one character to a file:
    - **process "rank=0" should write an 'a'**
    - **process "rank=1" should write an 'b'**
    - **...**
  - Use a 1-dimensional fileview with MPI_TYPE_CREATE_SUBARRAY
  - The pattern should be repeated 3 times, i.e., four processes should write: "abcdabcdabcd"
  - Please, substitute "____" in your `my_exa2.c / .f`
  - Compile and run your `my_exa2.c / .f`

MPI–IO Exercise 2: Using fileviews and individual filepointers, continued

etype = MPI_CHARACTER / MPI_CHAR

filetype process 0
filetype process 1
filetype process 2
filetype process 3

holes

tiling a file with filetypes:

a	b	c	d	a	b	c	d	a	b	c	d	file

file displacement = 0 (number of header bytes)

a	a	a	••••	view of process 0
b	b	b	••••	view of process 1
c	c	c	••••	view of process 2
d	d	d	••••	view of process 3

Shared File Pointer, I.

- same view at all processes mandatory!
- the offset is the current, *global* value of the **shared file pointer** of **fh**
- multiple calls [*e.g. by different processes*] behave as if the calls were serialized
- non-collective, e.g.

MPI_FILE_READ_SHARED(fh, *buf*, count, datatype, *status*)

- collective calls are *serialized* in the **order** of the processes' ranks, e.g.:

MPI_FILE_READ_ORDERED(fh,*buf*,count,datatype,*status*)

Shared File Pointer, II.

MPI_FILE_SEEK_SHARED(fh, offset, whence)

MPI_FILE_GET_POSITION_SHARED(fh, *offset*)

MPI_FILE_GET_BYTE_OFFSET(fh, offset, *disp*)

- same rules as with individual file pointers

Collective Data Access

- Explicit offsets / individual file pointer:
  - same as non-collective calls by all processes “of **fh**”
  - ***chance for best speed!!!***
- shared file pointer:
  - accesses are ordered by the ranks of the processes
  - optimization chance:
    - **first, locations within the file for all processes can be computed**
    - **then parallel physical data access by all processes**

Application Scenery, I.

- Scenery A:
  - Task: Each process has to read the whole file
  - Solution: MPI_FILE_READ_ALL
    = collective with individual file pointers,
    with same view (displacement+etype+filetype)
    on all processes
    [*internally: striped-reading by several process, only once from disk, then distributing with bcast*]
- Scenery B:
  - Task: The file contains a list of tasks,
    each task requires different compute time
  - Solution: MPI_FILE_READ_SHARED
    = non-collective with a shared file pointer
    (same view is necessary for shared file p.)

Application Scenery, II.

- Scenery C:
  - Task: The file contains a list of tasks,
    each task requires **the same** compute time
  - Solution: MPI_FILE_READ_ORDERED
    = **collective** with a **shared** file pointer
    (same view is necessary for shared file p.)
  - or: MPI_FILE_READ_ALL
    = **collective** with **individual** file pointers,
    different views: *filetype* with
    MPI_TYPE_CREATE_SUBARRAY(1,nproc,
    1, myrank, ..., datatype_of_task, *filetype*)
    [*internally: both may be implemented the same and equally with following scenery D*]

Application Scenery, III.

- Scenery D:
  - Task: The file contains a matrix,
    block partitioning,
    each process should get a block
  - Solution: generate different filetypes with
    MPI_TYPE_CREATE_DARRAY,
    the view on each process represents the block
    that should be read by this process,
    MPI_FILE_READ_AT_ALL with offset=0
    (= collective with explicit offsets)
    reads the whole matrix collectively
    [*internally: striped-reading of contiguous blocks by several process, then distributed with "alltoall"*]

Non-blocking Data Access

e.g. MPI_FILE_IREAD(fh, *buf*, count, datatype, *request*)
MPI_WAIT(request, *status*)
MPI_TEST(request, *flag, status*)

- analogous to MPI-1 non-blocking
- **non-standard** interface if ROMIO is used and not integrated:

MPI**O**_Request request
MPI_FILE_IREAD(fh, *buf*, count, datatype, *request*)
MPI**O**_WAIT(request, *status*)
MPI**O**_TEST(request, *flag, status*)

Split Collective Data Access, I.

- collective operations may be **split** into two parts:
  - start the split collective operation

e.g. MPI_FILE_READ_ALL_BEGIN(fh, *buf*, count, datatype)

  - complete the operation and return the **`status`**

MPI_FILE_READ_ALL_END(fh, *buf*, *status*)

Split Collective Data Access, II.

- Rules and Restrictions:
  - the MPI_...BEGIN calls are collective
  - the MPI_...END calls are collective, too
  - only one active (pending) split or regular collective operation per file handle at any time
  - split collective does not match ordinary collective
  - same **`buf`** argument in MPI_...BEGIN and ..._END call
- Chance to overlap file I/O and computation
- but also a valid implementation:
  - does all work within the MPI_...BEGIN routine, passes status in the MPI_...END routine
  - passes arguments from MPI_...BEGIN to MPI_...END, does all work within the MPI_...END routine

Scenery – Split Collective

- Scenery A:
  - Task: Each process has to read the whole file
  - Solution:
    - MPI_FILE_READ_ALL_BEGIN
      = collective with individual file pointers,
      with same view (displacement+etype+filetype)
      on all processes
      [*internally: starting asynchronous striped-reading by several process*]
    - then computing some other initialization,
    - MPI_FILE_READ_ALL_END.
      [*internally: waiting until striped-reading finished, then distributing the data with bcast*]

Other File Manipulation Routines

- Pre-allocating space for a file [*may be expensive*]
  MPI_FILE_ PREALLOCATE(fh, size)
- Resizing a file [*may speed up first writing on a file*]
  MPI_FILE_SET_SIZE(fh, size)
- Querying file size
  MPI_FILE_GET_SIZE(filename, ***size***)
- Querying file parameters
  MPI_FILE_GET_GROUP(fh, ***group***)
  MPI_FILE_GET_AMODE(fh, ***amode***)
- File info object
  MPI_FILE_SET_INFO(fh, info)
  MPI_FILE_GET_INFO(fh, ***info_used***)

MPI I/O Error Handling

- File handles have their own error handler
- Default is MPI_ERRORS_RETURN,
  i.e. **non-fatal**
  [vs message passing: MPI_ERRORS_ARE_FATAL]
- Default is associated with MPI_FILE_NULL
  [vs message passing: with MPI_COMM_WOLRD]
- Changing the default, e.g., after MPI_Init:
  MPI_File_set_errhandler(MPI_FILE_NULL, MPI_ERRORS_ARE_FATAL);
  CALL MPI_FILE_SET_ERRHANDLER(MPI_FILE_NULL,MPI_ERRORS_ARE_FATAL,*ierr*)
- MPI is *undefined* after first erroneous MPI call
- but a **high quality** implementation
  will support I/O error handling facilities

Implementation-Restrictions, I.

- MPICH 1.1.2 , mpt.1.3.0.1 on CRAY-T3E, HP MPI 1.4, ...
  - with ROMIO 1.0.1
- ROMIO 1.0.1
  - without shared file pointer routines
  - without MPI_MODE_SEQUENTIAL (as amode in MPI_FILE_OPEN)
  - without split collective routines
  - “status” is not filled in any function
  - EOF is not detected while reading and file pointer is set behind EOF
  - i.e. no chance to detect EOF via status or MPI_FILE_GET_POSITION
  - nonblocking with MPI**O**_Request, MPI**O**_Wait, MPI**O**_Test
  - returns only ierror = MPI_SUCCESS or MPI_ERR_UNKNOWN
  - only “native” data representation
  - without registering user-defined representations

Implementation-Restrictions, II.

- mpt.1.3.0.1 on T3E
  - only with I/O chapter, based on ROMIO
  - problems with MPI_TYPE_CREATE_DARRAY
    - empty blocks allowed but erroneous implementation
  - without parallel, striped file I/O --> only ~30 MB/s RAID
  - Work around for empty blocks and striped file I/O:
    - see www.hlrs.de/mpi/mpi_t3e.html#StripedIO
    - up to 200 MByte/sec parallel striped file I/O
      but only for applications using parallel collective I/O
      on large files (> 3 Mbyte / process)
    - with benchmark example exa_block.f
      www.hlrs.de/mpi/exa_block.f

Implementation-Restrictions, III.

- MPI-2 on the Fujitsu VPP
  - needs extra PE for a server process
    - to handle shared file pointers
    - to run on MPIFS caching file system
  - does not support Unix file system — implementation is underway
  - collective file access — optimization is underway

(state 1/2000)

MPI-I/O: Summary

- Rich functionality provided to support various data representation and access
- MPI I/O routines provide flexibility as well as portability
- Collective I/O routines can improve I/O performance
- Initial implementations of MPI I/O available (eg, ROMIO from Argonne)
- Available nearly on every MPI implementation

MPI–IO Exercise 3: Collective ordered I/O

- Copy to your local directory:
  cp ~/MPI/course/**C**/mpi_io/mpi_io_exa3_skel.c **my_exa3.c**
  cp ~/MPI/course/**F**/mpi_io/mpi_io_exa3_skel.f **my_exa3.f**
- Tasks:
  – Substitute the write call with individual filepointers by a collective write call with shared filepointers
  – Compile and run your `my_exa3.c / .f`

MPI–IO Exercise 4: I/O Benchmark

- Copy to your local directory:

```
cp ~/MPI/course/F/mpi_io/[am]* .
```

- You receive:

```
mpi_io_exa4.f
ad_ufs_open.o, ad_ufs_read.o, ad_ufs_write.o *)
```

- Tasks:
  - compile and execute mpi_io_exa4 on 4 PEs
  - compile and link with `ad_ufs*.o` and execute on 4 Pes *)
  - duplicate lines 65 –93 three times and substitute “WRITE_ALL” by “WRITE”, “READ_ALL”, “READ” and execute on 4 PEs
  - double the value of gsize and compile and execute on 8 PEs
  - link without `ad_ufs*.o` and execute on 8 Pes *)

  *) ad_ufs only on T3Es with striped file system