GeoPar

User's Guide and Reference Manual

Peter Altevogt*
Heidelberg Scientific & Technical Center
(HDSTC)
IBM Deutschland Informationssysteme GmbH
Vangerowstr. 18
69115 Heidelberg
Germany

Werner von Bloh†
Potsdam Institute for Climate Impact Research
(PIK)
Telegrafenberg
14473 Potsdam
Germany

*altevogt@heidelbg.ibm.com
†bloh@pik-potsdam.de

Trademarks and Service Marks

The following terms, denoted by an (*) at their first occurrence in this publication, are trademarks or registered trademarks:
AIX
IBM
RISC System/6000
SP1
SP2
RISC System/6000 Scalable POWERparallel Systems
RS/6000 Scalable POWERparallel Systems
RS/6000 SP

Abstract

The library **GeoPar** is a library to parallelize algorithms defined on simple cubic lattices (multidimensional arrays in C or Fortran) in two and three dimensions by. It provides an automatic distribution of the data on an arbritrary number of processors by associating appropriate sized simple cubic sublattices with the processors ("geometric parallelization" or "domain decomposition"). Furthermore, routines to access the data distributed over the processors, to exchange the data on the boundaries between neighbouring processors as well as for global I/O functions are available.

GeoPar is implemented as a parallel library using the MPI message passing interface and is meant to *supplement* MPI in providing a convenient parallelization of the above characterized class of applications, not to replace message passing.

In the first release of **GeoPar** , we have implemented the two dimensional version including the C bindings.

Contents

1 Introduction to GeoPar

During the last years, multiprocessor systems of the MIMD type with distributed memory have more and more become the appropriate systems to provide the computational resources for huge computer simulations. Especially the use of standard components like RISC processors used in mass–production of workstations in cluster–like system (e.g. the IBM RISC Systems/6000 Scalable POWERparallel Systems*) has drastically reduced the prices of such systems, increased their reliability and has resulted in a many similarities between the architectures of multiprocessor systems provided by various vendors. Besides other reasons, this led to a steady increase in the number of installations of multiprocessor systems of the MIMD type with distributed memory.
Although there exist quite a few programming models for the programming of such systems (e.g. the data parallel model, the virtual shared memory model, ...), the message passing model seems to be the most universal, expressive and best performing programming model. Furthermore, the existing MPI standard for message passing provides a portable, efficient application programming interface with a good functionality. However, in many applications based on simple cubic lattices, e.g. Ising–like models in statistical physics or "Daisyworld" models to simulate ecological systems, which are most natural parallelized by geometric parallelization resp. domain decomposition, associating simple cubic sublattices with the processors of the multiprocessor system, frequently the same simple communication patterns occur, e.g. the exchange of data defined on the boundaries of the sublattices between the processors.
The goal of the **GeoPar** library is to provide simple communication patterns, e.g. to update the data defined on the boundaries on all processors and thus to relief the user from the (tedious and error prone) task to *explicitly* implement these simple communications using the MPI message passing interface over and over again. Therefore, **GeoPar** is *not* a substitute for message passing, it rather *complements* the MPI message passing interface for the above specified class of applications.
Currently a tested implementation of **GeoPar** is supported for IBM 9076 SP2 systems, but there should be no major obstacle to implement **GeoPar** on other systems supporting the MPI message passing interface.
In the sequel we will first give an introduction to using **GeoPar** (Users's Guide) including concrete examples and then provide a complete overview over the functionality of **GeoPar** (Reference Manual).

2 User's Guide

2.1 Installation of GeoPar

GeoPar is provided in form of the "uuencoded" file `GeoPar.uu`.

2.2 Compiling and linking with GeoPar

For C programmers

To compile and link code using **GeoPar** library routines, the makefile may contain the following lines of code:

```
CC = mpicc
CFLAGS = -us
GPDIR=/usr/local/GeoPar
GPINCDIR=-I$(GPDIR)
GPLIB=$(GPDIR)/libGP2d.a
example: example.c
        $(CC) $(CFLAGS) $(GPINCDIR) $(GPLIB) example.c -o example
```

We have assumed that **GeoPar** is installed in the directory `/usr/local/GeoPar`. The installation directory contains the `GP2d.h` header file with the ANSI–C prototypes and macros and the library file `libGP2d.a`. Every application using **GeoPar** must include this header file, i.e. it must contain the following include directive before accessing a **GeoPar** function:

```
#include <GP2d.h>
```

For Fortran 90 programmers

The makefile may look as follows:

```
FC = mpxlf
FFLAGS = -g -O -U
GPDIR=/usr/local/GeoPar
GPINCDIR=-I$(GPDIR)
GPLIB=$(GPDIR)/libGP2d.a
example: example.f
        $(FC) $(FFLAGS) $(GPINCDIR) $(GPLIB) example.f -o example
```

Here the installation directory contains the GP2d.f header file with data declarations. This file must included by:

```
include "GP2d.f"
```

Attention!!! The Fortran 90 interface assumes that the compiler arranges complex data structures in the memory like a C compiler.

Running the program

To execute a program, various environment variables on an IBM RS/6000 SP system must be set. If e.g. the program `example` requires 4 tasks, we want to use the *User Space* protocol via the *High Performance Switch* for communication

and the *pool* of processors[1] we want to use is identified by "1", the parameter list would look as follows (using the Korn shell):

```
export MP_PROCS=4
export MP_EUIDEVICE=css0
export MP_EUILIB=us
export MP_RMPOOL=1
```

The parameters may be provided explicitely to the shell via the command line or be part of a shell script. For further details read the user's guide for MPI/POE???.

2.3 Example: "Game of Live"

2.3.1 Introduction

To demonstrate the use of various **GeoPar** functions, we implement a simple application, called the "Game of Life". The "Game of Life" is a cellular automaton defined on a rectangular simple cubic lattice in two dimensions and was introduced by John Conway in 1970. On each site of the lattice there exists a cell having only two states, "dead" and "alive". The evolution of the states of the cells is determined by two simple rules, which depend only on the state of the cell and it's neighbors (see, e.g., Fig. 1):

Cell is "alive": Will remain "alive", if number of living neighbours is 2 or 3, otherwise will be "dead".

Cell is "dead": Will be "alive" if number of living neighbours is exactly 3, otherwise it will remain "dead".

Implementing the "Game of Life" in C, an adequate type definition for a cell is given by

```
typedef enum {DEAD=0,LIVE=1} STATE;
```

The lattice is then defined as

```
STATE lattice[sizex][sizey];
```

and the update rule for the "Game of Life" may be implemented in C as follows:

```
STATE updatestate(const STATE **state,int x1,int x2)
{
  int count;
  /*
   *  Count living neighbor cells of cell (x1,x2):
   */
  count =  state[x1-1][x2-1]+state[x1  ][x2-1]
```

[1] The command `jm_status -P` gives an overview over the defined *pools* on an IBM RS/6000 SP system.

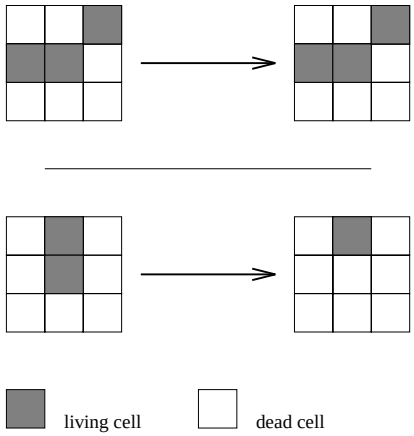


Figure 1: Two different states of the cellular automaton. In the first case the cell(in the middle) will remain "living", while in the second one the cell will die out.

```
          +state[x1+1][x2-1]+state[x1-1][x2  ]
          +state[x1+1][x2  ]+state[x1-1][x2+1]
          +state[x1  ][x2+1]+state[x1+1][x2+1];
  /*
   *  Update rules of ‘‘Game of Life’’:
   */
  if(state[x1][x2]==LIVE)
    return (count==2 || count==3) ? LIVE : DEAD;
  else
    return (count==3) ? LIVE : DEAD;
}
```

A typical configuration of the cellular automaton is shown in Fig. 2.

2.3.2 Parallelization using GeoPar

The first step in a parallelization using the **GeoPar** library is to initialize the parameters of the simulation using the `struct GP2d_InputParams` as defined in `GP2d.h`:

```
typedef struct
{
  int LattSize[2];
  int NumProcs[2];
  int Periods[2];
  int Reorder;
  int *Partition[2];
  int BoundaryWidth[2];
  size_t CellSize;
  MPI_Comm Communicator;
} GP2d_InputParams;
```

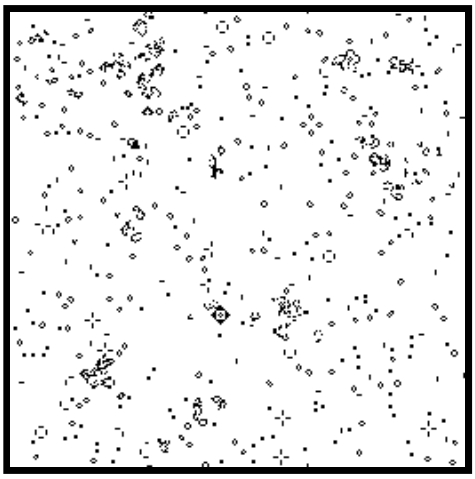


Figure 2: A typical configuration of the cellular automation after 1000 iterations started from a random distribution.

The array `LattSize` describes the lattice sizes of the lattice, the array `NumProcs` describes the lattice sizes of the "processor lattice", i.e. the simulation is executed in parallel on a Cartesian lattice of processors of size `NumProcs[0]` × `NumProcs[1]`, the array `Periods` specifies whether the lattice is periodic (1) or not (0) in each dimension and the array `BoundaryWidth` describes the widths of the boundaries of the lattice that have to be communicated to the neighbouring processors. In general, these parameters are closely related to the "interaction radii" of the algorithms under consideration. For example, for an Ising model based on a nearest–neighbour interaction, the widths would be equal to one for all dimensions. The integer `Reorder` is used specify whether the MPI Library can rearrange(1) the processors while creating a virtual processor grid or not(0). The variable `Communicator` contains an id that is used for communication in MPI. This id is given by a library initialization function. The array `Partition` consists of pointer to an int array of length `NumProcs[i]`. It defines the number of cells, which are distributed to the task in direction `i`. If the pointer is set to NULL the library will choose a balanced distribution. Fig. 3 shows a typical distribution of a lattice to 4 tasks with an interaction radius of one. The structure component `CellSize` finally defines the size of the "cell" (i.e. the size of the data structure associated with the lattice sites) itself, usually initialized by a call to the `sizeof` operator.
The struct `GP2d_InputParams`, included in the struct `GP2d`, is then used by the routine `GP2d_Initialize()` to initialize the generic data structure `GP2d` of **GeoPar** which contains the basic informations about the lattice and it's distribution on the processors. For our example this would look like follows:

```
GP2d_InputParams InputParams;
GP2d *gp;
...
gp->InputParams.LattSize[0]=100;
```

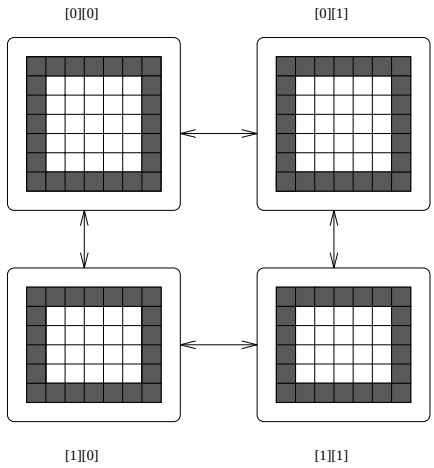


Figure 3: Distributed array on 4 tasks. The dark grid cells are the "ghost" cells from the neighbored tasks.

```
gp->InputParams.LattSize[1]=100;
gp->InputParams.NumProcs[0]=2;
gp->InputParams.NumProcs[1]=2;
gp->InputParams.BoundaryWidth[0]=1;
gp->InputParams.BoundaryWidth[1]=1;
gp->InputParams.Reorder=TRUE;
gp->InputParams.Periods[0]=TRUE;
gp->InputParams.Periods[1]=TRUE;
gp->InputParams.Partition[0]=NULL;
gp->InputParams.Partition[1]=NULL;
gp->InputParams.CellSize=sizeof(STATE);
gp->InputParams.Communicator=MPI_COMM_WORLD;

MPI_Init(&argc, &argv);

GP2d_Initialize(gp);
```

Before the function `GP2d_Initialize()` is called, you must initialize the MPI environment by calling the function `MPI_Init(...)`. The function `GP2d_Initialize()` initializes the `GP2d` struct. All **GeoPar** functions need the pointer `gp` as their first argument, direct access to the `GP2d` struct should be avoided because future releases of **GeoPar** could change its structure.
The lattice itself is allocated by a call to `GP2d_CreateLatt()` returning a generic pointer of type `void **` that must be casted to the correct type.Fig. 4 illustrates the dynamic structure created by `GP2d_CreateLatt()`.
The content of the sublattices is undefined and may be initialized by using the `GP2d_FillLatt()` function, e.g.:

```
STATE cell;
STATE **lattice;
cell=DEAD;
```

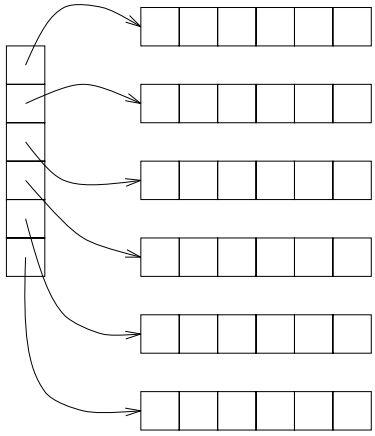


Figure 4: Dynamic structure of the distributed lattice created by a call to `GP2d_CreateLatt()`.

```
lattice=(STATE **)GP2d_CreateLatt(gp);
GP2d_FillLatt(gp,lattice,&cell);
```

Individual cells may be initialized by using `GP2d_SetCell()`:

```
cell=LIVE;
GP2d_SetCell(gp,lattice,100,100,&cell);
```

The function is executed on every process, but only the process "owning" the cell updates its value and returns TRUE, all other tasks return FALSE.

2.4 Accessing the lattice

Direct access to the lattice is restricted to the local sublattice "owned" by the processor, including the "ghost elements" allocated to store data from neighbouring processes. The position of the local lattice (relative to the coordinates of the global lattice) can be determined by a call to the `GP2d_GetLowCoordX1()`, `GP2d_GetHighCoordX1()`, `GP2d_LowCoordX2()` and `GP2d_GetHighCoordX2()` functions. Direct access to a cell with coordinates (x_1, x_2) is only possible if

$$\begin{aligned}&\texttt{GP2d\_GetLowCoordX1(gp)} - \texttt{GP2d\_GetBoundaryWidth(gp)}[0]\\ &\leq x_1 <\\ &\texttt{GP2d\_GetHighCoordX1(gp)} + \texttt{GP2d\_GetBoundaryWidth(gp)}[0]\end{aligned}$$

and

$$\begin{aligned}&\texttt{GP2d\_GetLowCoordX2(gp)} - \texttt{GP2d\_GetBoundaryWidth(gp)}[1]\\ &\leq x_2 <\\ &\texttt{GP2d\_GetHighCoordX2(gp)} + \texttt{GP2d\_GetBoundaryWidth(gp)}[1]\end{aligned}$$

holds.
The function `GP2d_IsinMyLatt(gp,x1,x2)` returns a boolean value, whether the coordinates are in the local lattice or not and can be used to test on the validity of an read/write access.
Then the (preliminary) parallelized "update rule" for our example looks as follows:

```
void updategol(GP2d *gp,STATE **newstate,const STATE **oldstate)
{
  int x1,x2;
  for(x1=GP2d_GetLowCoordX1(gp);x1<GP2d_GetHighCoordX1(gp);x1++)
    for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
       newstate[x1][x2]=updatestate(oldstate,x1,x2);
}
```

This function updates in parallel the complete lattice. Because of iterations over the complete lattice being performed frequently, **GeoPar** provides the following macro `GP2d_ForAll()` for performing the two nested loops:

```
  GP2d_ForAll(gp,x1,x2)
    newstate[x1][x2]=updatestate(oldstate,x1,x2);
```

Accessing elements outside the boundaries of the local lattice results in an "access violation" with unpredictable behavior. The `GP2d_SetCell()` must be used if the contents of a lattice cell has to be changed. function `GP2d_IsInMyLatt()` may be used to check whether the lattice element is local or not. To read the contents of an arbitrary cell (local or not), the `GP2d_GetCell()` function can be used. The process owning the cell broadcasts it to all processes; therefore calls of `GP2d_GetCell()` should be restricted to a minimum.

2.5 Updating the boundaries

After initializing or updating the cells of the lattice, the "ghost cells" must also be updated. This requires the communication of the boundary cells between processes. If we use periodic boundary conditions for the whole lattice, `GP2d_UpdBnd()` performs automatically the required communication processes. Therefore, the final version of our update function looks as follows:

```
void updategol(GP2d *gp,STATE **newstate,const STATE **oldstate)
{
  int x1,x2;
  GP2d_ForAll(gp,x1,x2)
    newstate[x1][x2]=updatestate(oldstate,x1,x2);
  GP2d_UpdBnd(gp,newstate);
}
```

2.6 I/O-Functions

The complete lattice can be read or written to a file by the use of `GP2d_FReadLatt()` respectively `GP2d_FWriteLatt()`. These functions provide a mechanism for compression of the data before writing them to a file by a call to a user defined function. This functions operates on one column of the local sublattice and writes the compressed data into a buffer. To compress the data from an int format to one byte one has to code

```
void compresscolumn(GP2d *gp,char *buffer,const int *column)
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
   *buffer++=(char)column[x2];
}
```

Using the above defined compress function, the configuration of our cellular automaton can be written to disk as follows:

```
void writegol(GP2d *gp,STATE **lattice,FILE *file)
{
  GP2d_FWriteLatt(gp,lattice,file,compresscolumn,sizeof(char),TASK);
}
```

If no compression is necessary, instead of `compresscolumn()` a `NULL` pointer can be used in the call of `GP2d_FWriteLatt()`.
Analogous to the `GP2d_FWriteLatt()` function it is possible to read the lattice using the `GP2d_FReadLatt()` function. Instead of a compress function a decompress function must be defined:

```
void decompresscolumn(GP2d *gp,int *column,const char *buffer)
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
     column[x2]=(int)(*buffer++);
}
```

A complete listing of the parallelized "Game of Life" simulation using the **GeoPar** library is presented in the appendix.

2.7 Limitations of GeoPar

A 2-dimensional lattice of size $N \times M$ *must* consist of cell elements of the same type. The type of cell elements can be int, float or even complex structs with one restriction: All components must be static types, no pointers are allowed. For example

```
typedef int CELL1_T;
typedef float CELL2_T;
typedef struct
{
  int count;
  double koord[3];
}CELL3_T; /* Valid declarations */
```

are valid declarations, while

```
typedef struct
{
  int len;
  float *vector; /* Pointer to a vector */
}CELL_T; /* Invalid data type */
```

not. The interaction and dependencies between the cell elements must be local, i.e. limited to a finite distance. The efficiency is improved if this interaction radius is limited to the next neighborhood of the cells.

2.8 Performance considerations

In this section we want to estimate the efficiency, defined as

$$E(p) := \frac{T(1)}{p \times T(p)}, \tag{1}$$

where $T(p)$ denotes the computing time of the algorithm on p processors.
If T_{calc} is the time required for updating one cell, then the time of updating the whole lattice of N cells is determined by

$$T(1) = NT_{calc}. \tag{2}$$

If the transfer of one cell element requires T_{comm} time with a latency of T_{lat}, then the update of the neighbouring cells with interaction radius k on p processors requires

$$T_{update}(p) = 8\left(T_{lat} + k\sqrt{\frac{N}{p}}T_{comm}\right). \tag{3}$$

Thus the computation time of the parallelized version on p processors is

$$T(p) = \frac{N}{p}T_{calc} + 8\left(T_{lat} + k\sqrt{\frac{N}{p}}T_{comm}\right). \tag{4}$$

Using eq. 2 and 4 we get for $E(p)$:

$$E(p) = \frac{1}{1 + 8\left(\frac{p}{N}\frac{T_{lat}}{T_{calc}} + \sqrt{\frac{p}{N}}k\frac{T_{comm}}{T_{calc}}\right)} \tag{5}$$

The efficiency is increased by increasing N. See, e.g. Fig. 5, which plots for different lattice sizes N the efficiency as a function of p.

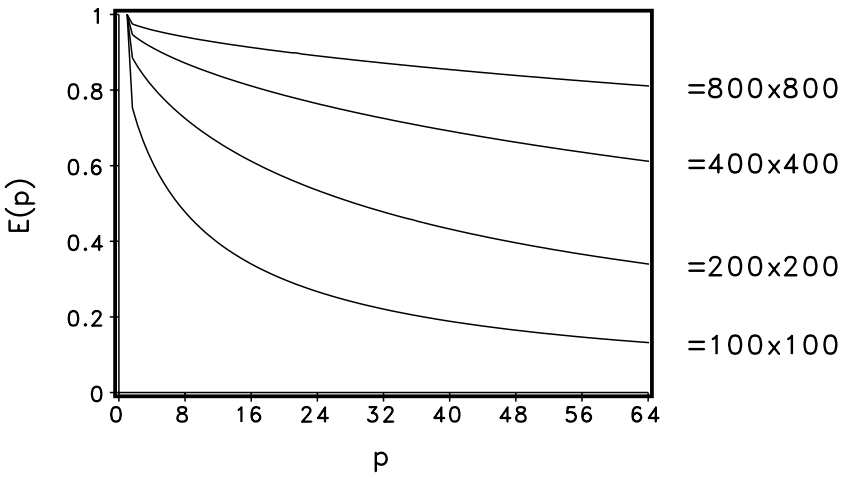


Figure 5: Efficiency as a function of processor counts p for different lattice sizes N.

3 REFERENCE GUIDE

3.1 Functions listed alphabetically

NAME **GP2d_BCastData** - Broadcast data to each task. One task broadcast simple or complex data to the other tasks.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_BCastData(GP2d *gp, void *data,
                    size_t datasize, int source );
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_BCastData(GP2d gp, INTEGER data,
                INTEGER datasize, INTEGER source )
```

PARAMETERS

gp The struct containing informational parameters.

data Points to the data at the sender, or points to the the place where the data can be stored at the receiver.

datasize Size of the data in bytes.

source The identifier of the sender.

DESCRIPTION The aim of this function is to send a piece of memory to all participating tasks. If you use this in Fortran 90, data will be the name of a simple variable or struct. The task that id is given as source will be the sender of the data, the other tasks will receive this data.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

source Not in the range

- 0 . . . GP2d_GetNumProcs(gp)[0]
  × GP2d_GetNumProcs(gp)[1] − 1, in C;
- 0 . . . gp%NUMPROCS(1)
  ×gp%NUMPROCS(2) − 1, in Fortran 90.

C EXAMPLE

```
#include "GP2d.h"
#define ROOTTASK 0

void main(void)
{
```

```
  GP2d gp = { {{100,200},{4,4},{0,0},0,{NULL,NULL},
               {1,1},sizeof(int),0,0},
              0,0,0,0,0,{0,0},{0,0},{0,0},{0,0},
              {0,0},{0,0}};
  GP2d *p_gp = &gp;
  int dim[2] = {100, 200}, array[100][200], i, j;

  GP2d_Initialize(p_gp);

  if (GP2d_MyTaskId(p_gp) == ROOTTASK)
  {
    for(i=0;i<dim[0];i++)
      for(j=0;j<dim[1];j++) array[i*dim[1]+j] = i*j;
  }
  GP2d_BCastData(p_gp, array, sizeof(int)*dim[0]*dim[1],
                 ROOTTASK);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program BCAST
use GEOPAR

  type (GP2D) GP
  integer ARRAY(0:99, 0:199), DIM(0:1)
  integer I, J, IERR

  DIM(0) = 100
  DIM(1) = 200
  GP%INPUTPARAMS%NUMPROCS(1) = GP2d_COMPUTE

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  if (GP%MYTASKID == 0) then
    do I=0, DIM(0)-1
      do J=0, DIM(1)-1
        ARRAY(I,J) = I*J
      end do
    end do
  end if

  call GP2DF_BCastData(GP, ARRAY, 4*DIM(0)*DIM(1), 0)
end
```

NAME **GP2d_Collect** - Collect lattice to one task. Simply collect the distributed lattice and put the sublattices at the correct (see GP2d_Gather?!) places

C SYNOPSIS

```
#include <GP2d.h>
typedef void (*GP2d_CollectFunction) (GP2d*, void *,int, void *);
void GP2d_Collect(GP2d *gp, void *data, void **lattice,
                  GP2d_CollectFunction fcn, int taskid);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_Collect(GP2d gp, INTEGER data, INTEGER lattice,
              INTEGER fcn, INTEGER taskid)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

data Some extra information that will be submitted to the "collect function" fcn.

lattice The pointer to the the distributed lattice.

fcn Pointer to a function, that is executed on the process with taskid **taskid**. The first parameter of the function is a pointer to the sublattices, the second is the extra information (see parameter data), the third is the column number of the lattice, while the fourth is a pointer to one column of the whole lattice.

taskid The task identifier, where the data will be sent and the function will be evaluated.

DESCRIPTION The aim of this function is to allow a column-ordered output of the lattice to one designated task. The output function is defined by the third parameter and is called in column order for each column. This function requires the sending of the whole lattice to one task, therefore excessive calls to this function should be avoided due to performance decrease. The data parameter can be used to submit information, like strings etc., to the collector.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

fcn Pointer to an invalid function.

taskid Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0]
  × GP2d_GetNumProcs(gp)[1] − 1, in C;
- 0 ... gp%NUMPROCS(1)
  ×gp%NUMPROCS(2) − 1, in Fortran 90.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0

void printline(GP2d *gp,void *data, int x1,int *cell)
{
  int x2;
  printf("%3d ",x1);
  for(x2=0;x2<GP2d_GetLattSize(gp)[1];x2++)
    if(cell[x2])
      printf("*");
    else
      printf(" ");
  printf("\n");
}

void initlattice(GP2d *gp,int **lattice)
{
  int x1,x2;
  GP2d_ForAll(gp,x1,x2)
    lattice[x1][x2]=x1+x2;
}

void main(void)
{
  GP2d gp={{40,10}, {2,2}, {True, True}, {True},
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_pg = &gp;
  int **lattice;
  GP2d_Initialize(p_gp);
  lattice=(int **) GP2d_CreateLatt(p_gp, NULL);
  initlattice(p_gp,lattice);
  GP2d_Collect(p_gp,NULL,lattice,printline,ROOTTASK);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program COLLECT
use GEOPAR

subroutine INITLATT(LP, LATT)
  use GEOPAR
  type (GP2D) LP
  integer LATT (LP%LOW(2):LP%HIGH(2), LP%LOW(1):LP%HIGH(1))

  integer I, J

  do I=LP%LOWCOORDS(1), LP%HIGHCOORDS(1)-1
    do J=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
      LATT(J,I) = J+I
    end do
  end do
end subroutine INITLATT

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, PTR
  external PrintColumn

  GP%INPUTPARAMS%LATTSIZE(1) = 40
  GP%INPUTPARAMS%LATTSIZE(2) = 20

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, PTR)
```

```
  call INITLATT(GP, ARRAY)
  call GP2DF_Collect(GP, 0, PTR, PrintColumn, 0)
end
```

NAME **GP2d_CopyLatt** - Copy lattice.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_CopyLatt(GP2d *gp, void **dest, void **source);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_CopyLatt(GP2d gp, INTEGER dest, INTEGER source)
```

PARAMETERS

gp Pointer to the struct containing informational parameters.

dest Pointer to a sublattice to which the data should be copied.

source Pointer to the sublattice to be copied.

DESCRIPTION The function copies the contents of one distributed lattice to a second one.

ERRORS

gp Not initialized by GP2d_Initialize.

dest Invalid pointer or not initialized by GP2d_CreateLatt.

source Invalid pointer or not initialized by GP2d_CreateLatt.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, {True},
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice,**aux;

  GP2d_Initialize(p_gp);

  lattice = (int **) GP2d_CreateLatt(p_gp, NULL);
  aux     = (int **) GP2d_CreateLatt(p_gp, NULL);
  GP2d_CopyLatt(gp, aux, lattice);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program COPY_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: SOURCE (:,:), DESTINATION (:,:)
  integer  IERR, SOURCE_PTR, DESTINATION_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(SOURCE(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  allocate(DESTINATION(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, SOURCE, SOURCE_PTR)
  call GP2DF_CreateLatt(GP, DESTINATION, DESTINATION_PTR)

  call GP2DF_CopyLatt(GP, DESTINATION_PTR, SOURCE_PTR)
end
```

NAME **GP2d_CreateGlobalLatt** - Create a complete lattice.

C SYNOPSIS

```
#include <GP2d.h>
void **GP2d_CreateGlobalLatt(GP2d *gp, void *lattice);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_CreateGlobalLatt(GP2d gp, INTEGER lattice, INTEGER ptr)
```

PARAMETERS

gp Pointer to the struct containing informational parameters.

lattice In C equal to zero. Contains in Fortran a pointer to the array.

ptr Contains a pointer to the lattice after the execution.

RETURN VALUE A pointer to the new complete lattice.

DESCRIPTION The function allocates memory for an undistributed lattice. One should be aware of the memory demands especially for large lattices and a large number of tasks.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
#define TASK 0
int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice, **clattice;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  if(GP2d_GetMyTaskId(p_gp) == TASK)
  {
    clattice = (int **) GP2d_CreateGlobalLatt(p_gp);
```

```
    for(x1=0;x1<GP2d_GetLattSize(p_gp)[0];x1++)
      for(x2=0;x2<GP2d_GetLattSize(p_gp)[1];x2++)
        clattice[x1][x2] = 2;
  }
  GP2d_Scatter(gp, lattice, clattice, TASK);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program CREATE_GLOBAL_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:), GLOBAL_ARRAY (:,:)
  integer  IERR, ARRAY_PTR, GLOB_ARY_PTR, I, J

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  if (GP%MYTASKID == 0) then
      allocate(GLOBAL_ARRAY(1:GP%INPUTPARAMS%LATTSIZE(2),
                            1:GP%INPUTPARAMS%LATTSIZE(1)))
      call GP2DF_CreateGlobalLatt(GP, GLOBAL_ARRAY, GLOB_ARY_PTR)
      do I=1, GP%INPUTPARAMS%LATTSIZE(2)
        do J=1, GP%INPUTPARAMS%LATTSIZE(1)
          GLOBAL_ARRAY(I,J) = 2
        end do
```

```
      end do
  end if
  call GP2DF_Scatter(GP, ARRAY_PTR, GLOB_ARY_PTR, 0)
end
```

RELATED INFORMATION

Functions: GP2d_FreeGlobalLatt/GP2DF_FreeGlobalLatt, GP2d_Gather/GP2DF_Gather, GP2d_Scatter/GP2DF_Scatter.

NAME **GP2d_CreateLatt** - Create a distributed lattice.

C SYNOPSIS

```
#include <GP2d.h>
void **GP2d_CreateLatt(GP2d *gp, void *lattice);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_CreateLatt(GP2d gp, INTEGER lattice, INTEGER ptr)
```

PARAMETERS

gp Pointer to the struct containing informational parameters.

lattice In C equal to zero. Contains in Fortran a pointer to the array.

ptr Contains a pointer to the lattice after the execution.

RETURN VALUE A pointer to the new distributed lattice.

DESCRIPTION The functions allocates a distributed lattice. The returned pointer should be casted to the type of the lattice cells.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

EXAMPLES

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program CREATE_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
end
```

RELATED INFORMATION

Functions: GP2d_FreeLatt/GP2DF_FreeLatt.

NAME **GP2d_FillLatt** - Fill lattice with one cell.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_FillLatt(GP2d *gp,void **lattice,const void *cell);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_FillLatt(GP2d gp, INTEGER lattice, INTEGER cell)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the the distributed lattice.

cell The lattice element that is copied to all cells of the lattice.

DESCRIPTION The function fills the whole lattice with one lattice element. This routine is useful for initialization of the lattice configuration. The shadowed boundary cells are not filled and must be updated by a call to GP2d_UpdBnd/GP2DF_UpdBnd.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

cell Not a valid pointer.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
typedef struct
{
  int count;
  int value;
} CELL_T;

void main(void)
{
  CELL_T cell={10,213};
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(CELL_T), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
```

```
          {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  CELL_T **lattice;
  GP2d_Initialize(p_gp);
  lattice = (CELL_T **) GP2d_CreateLatt(p_gp);
  GP2d_FillLatt(gp,lattice,&cell);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

module TYPES
  type CELL_T
    integer COUNT, VALUE
  end type CELL_T
end module TYPES

program FILL_LATT
use GEOPAR
use TYPES

  type (GP2D) GP
  type (CELL_T) CELL
  type (CELL_T), pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 8

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
```

```
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  CELL%COUNT = 10
  CELL%VALUE = 213
  call GP2DF_FillLatt(GP, ARRAY_PTR, CELL)
end
```

NAME **GP2d_FReadLatt** - Read lattice from a file. Simply read distributed lattice from file and distribute

C SYNOPSIS

```
#include <stdio.h>
#include <GP2d.h>
int  GP2d_FReadLatt(GP2d *gp,void **lattice,FILE *file,
                    GP2d_IOFunction iofcn,
                    GP2d_TransferFunction tfcn,
                    int bufelsize,int sourcetask);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_FReadLatt(GP2d gp, INTEGER lattice, INTEGER file,
                INTEGER iofcn, INTEGER tfcn,
                INTEGER bufelsize, INTEGER sourcetask, INTEGER ierr)
```

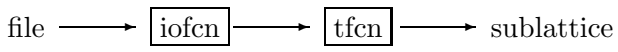
PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the distributed lattice.

file The file descriptor the data is read. (You can open a file with the function GP2DF_FOpen in Fortran.)

iofcn This function reads the data from the file. Here is a diagram of the principle of reading data from a file into a sublattice:



tfcn A function implementing a transformation of the data after reading them from the file with iofcn. The function is called for all columns of the sublattice. If set to NULL, no decompression is performed.

bufelsize The size of the data object stored in the file representing one cell. Is neglected, if **iofcn** is set to NULL.

sourcetask The task identifier of the task, that reads the file and distributes the data to all other tasks.

ierr Return value.

DESCRIPTION The function allows the restoring of a lattice configuration from one file. It is possible to decompress the data to save disk space and communication time. This decompress function(tfcn) processes one column of each sublattice. See the example for a correct implementation of a decompressing function. In **GeoPar** is one function GP2d_StdRead predefined, which performs no decompression at all. The boundary cells of the sublattices are not updated.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

file Invalid file pointer.

iofcn Pointer to an invalid read function.

tfcn Pointer to an invalid decompress function.

bufelsize Less than zero.

sourcetask Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0]
  × GP2d_GetNumProcs(gp)[1] − 1, in C;
- 0 ... gp%NUMPROCS(1)
  ×gp%NUMPROCS(2) − 1, in Fortran 90.

C EXAMPLE
Program reads the contents of the lattice from a file.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0

typedef struct {
int height;
int color;
} surface;

void read_fcn(FILE *file, char *buffer, size_t *bufsize, int *nelem)
{
  int i;
  for(i=0;i<*nelem;i++)
  {
    fscanf(file, "(%i,%i)\n", buffer+i*(*bufsize),
        buffer+i*(*bufsize)+sizeof(int));
```

```
  }
}

void decompresscolumn(GP2d *gp, surface *column, char * buffer)
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
  {
    column[x2].height = (int)(*buffer++);
    column[x2].color  = (int)(*buffer++);
  }
}

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(surface), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  surface **lattice;
  GP2d_Initialize(p_gp);
  lattice = (surface **) GP2d_CreateLatt(p_gp);
  FILE *file;
  if(GP2d_GetMyTaskId(p_gp)==ROOTTASK)
    if((file=fopen("test.cfg","rb"))==NULL)
    {
      fprintf(stderr,"Error opening file.\n");
      exit(EXIT_FAILURE);
    }
  GP2d_FReadLatt(p_gp, lattice, file, read_fcn, decompresscolumn,
    sizeof(surface),ROOTTASK);
  if (GP2d_GetMyTaskId(p_gp)==ROOTTASK)
    fclose(file);
  GP2d_UpdBnd(p_gp, lattice);
  exit(EXIT_SUCCESS);
}
```

FORTRAN 90 EXAMPLE

There is a little difference to the C version. While in C it is assumed that the values in the file are readable, this is not so in FORTRAN.

```
include "GP2d.f"

  module TYPES
    type SURFACE
      integer HEIGHT
```

```
    integer COLOR
  end type SURFACE
end module TYPES

subroutine READ_FCN(FILE, BUFFER, BUFSIZE, NELEM)
  use GEOPAR

  integer BUFSIZE, NELEM
  character, dimension(:) :: BUFFER
  integer FILE
  integer i,j

  do i=0, NELEM-1
    do j=1, BUFSIZE
      read (FILE, ADVANCE='NO') BUFFER(i*BUFSIZE+j)
    end do
  end do
end subroutine READ_FCN

subroutine DECOMPRESSCOLUMN(LP, COLUMN, BUFFER)
  use GEOPAR
  use TYPES

  type (GP2D) LP
  type (SURFACE) COLUMN(LP%LOWCOORDS(2):LP%HIGHCOORDS(2))
  integer BUFFER(0:2*(LP%HIGHCOORDS(2)-LP%LOWCOORDS(2)+1))
  integer i,j

  i=0
  do j=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
    COLUMN(j)%HEIGHT = BUFFER(i)
    i = i + 1
    COLUMN(j)%COLOR  = BUFFER(i)
  end do
end subroutine DECOMPRESSCOLUMN

program FREAD_LATT
  use GEOPAR
  use TYPES

  type (GP2D) GP
  type (SURFACE), pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, FILE

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100
```

```
  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 8

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  if (GP%MYTASKID == 0) then
    open(13, FILE='test.cfg',STATUS='OLD')
  end if

  call GP2DF_FReadLatt(GP, ARRAY_PTR, 13, READ_FCN,
    DECOMPRESSCOLUMN, 8,0)
  if (GP%MYTASKID == 0) then
    close(13)
  end if
  call GP2DF_UpdBnd(GP, ARRAY_PTR)
end
```

RELATED INFORMATION

Functions: GP2d_FStdReadLatt, GP2d_FWriteLatt/GP2DF_FWriteLatt.

NAME **GP2d_Free** - Free lattice structure.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_Free(GP2d *gp);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_Free(GP2d gp)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

DESCRIPTION This functions deallocates the memory of the informational struct(in C) and releases the MPI-Communicator. After this operation no **GeoPar** routine except GP2d_Initialize/GP2DF_Initialize can be invoked.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

EXAMPLES

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d gp1 = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp1 = &gp1;
  GP2d gp2 = {{50,50},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp2 = &gp2;
  int **lattice;
  GP2d_Initialize(p_gp1);
  lattice = (int **) GP2d_CreateLatt(p_gp1);

  GP2d_Free(p_gp1);
  GP2d_Initialize(p_gp2);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program FREE
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 8

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  call GP2DF_Free(GP)
  GP%INPUTPARAMS%LATTSIZE(1)=50
  GP%INPUTPARAMS%LATTSIZE(2)=50
  call GP2DF_Initialize(GP, IERR)
end
```

RELATED INFORMATION

Functions: GP2d_Initialize/GP2DF_Initialize.

NAME **GP2_FreeGlobalLatt** - Free complete lattice.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_FreeGlobalLatt(GP2d *gp,void **lattice);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_FreeGlobalLatt(GP2d gp, INTEGER lattice)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice Pointer to the complete lattice.

DESCRIPTION This functions deallocates the memory of a undistributed lattice.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateGlobalLatt/GP2DF_CreateGlobalLatt.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateGlobalLatt(p_gp);
  GP2d_FreeGlobalLatt(p_gp,lattice);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program FREE_GLOBAL_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateGlobalLatt(GP, ARRAY, ARRAY_PTR)
  call GP2DF_FreeGlobalLatt(GP, ARRAY_PTR)
end
```

RELATED INFORMATION

Functions: GP2d_CreateGlobalLatt/GP2DF_CreateGlobalLatt.

NAME **GP2_FreeLatt** - Free distributed lattice.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_FreeLatt(GP2d *gp,void **lattice);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_FreeLatt(GP2d gp, INTEGER lattice)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice Pointer to the distributed lattice.

DESCRIPTION This functions deallocates the memory of a distributed lattice.

ERRORS

gp Not initialized by GP2d_Initialize.

lattice Not allocated by GP2d_CreateLatt.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  GP2d_FreeLatt(p_gp,lattice);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program FREE_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  call GP2DF_FreeLatt(GP, ARRAY_PTR)
end
```

RELATED INFORMATION

Functions: GP2d_CreateLatt/GP2DF_CreateLatt.

NAME **GP2d_FWriteLatt** - Write lattice to a file. Simply collect and write distributed lattice to file

C SYNOPSIS

```
#include <stdio.h>
#include <GP2d.h>
int  GP2d_FWriteLatt(GP2d *gp, void* lattice, FILE *file,
                     GP2d_IOFunction iofcn,
                     GP2d_TransferFunction tfcn,
                     int bufelsize, int desttask);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_FWriteLatt(GP2d gp, INTEGER lattice, INTEGER file,
                 INTEGER iofcn, INTEGER tfcn,
                 INTEGER bufelsize, INTEGER desttask, INTEGER ierr)
```

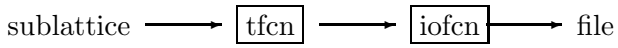
PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the distributed lattice.

file The file descriptor the data is written.

iofcn This function writes the data to the file. Here is a diagram of the principle of writing data from a sublattice into a file:



tfcn A function implementing a transformation of the data before writing them to the file with iofcn. The function is called for all columns of the sublattice. If set to Null no compression is performed.

bufelsize The size of the data object stored in the file representing one lattice element. Is neglected if **iofcn** is set to NULL.

desttask The task identifier of the task, that collects the data and writes the file.

ierr Return value.

DESCRIPTION The function allows the storing of a lattice configuration to one file. It is possible via a definition of a function to compress the data to save disk space and communication time. This function processes one column of each sublattice. See the example for a correct implementation of a compressing function.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

file Invalid file pointer.

iofcn Pointer to an invalid write function.

tfcn Pointer to an invalid compress function.

bufelsize Less than zero.

desttask Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0]
  × GP2d_GetNumProcs(gp)[1] − 1, in C;
- 0 ... gp%NUMPROCS(1)
  ×gp%NUMPROCS(2) − 1, in Fortran 90.

C EXAMPLE

The program stores a surface lattice(see FReadLatt) reduced to two integer into a file.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0

typedef struct {
int height;
int color;
} surface;

void write_fcn(FILE *file, char *buffer, size_t *bufsize, int *nelem)
{
  int i;
  for(i=0;i<*nelem;i++)
  {
    fprintf(file, "(%i,%i)\n", buffer+i*(*bufsize),
        buffer+i*(*bufsize)+sizeof(int));
  }
}

void compresscolumn(GP2d *gp, char *buffer, surface *column)
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
  {
```

```
    *buffer++ = (int)(column[x2].height);
    *buffer++ = (int)(column[x2].color);
  }
}

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(surface), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  surface **lattice, cell = { 100, 22 };
  GP2d_Initialize(p_gp);
  lattice = (surface **) GP2d_CreateLatt(p_gp);
  FILE *file;

  GP2d_FillLatt(p_gp, lattice, &cell);
  if (GP2d_GetMyTaskId(p_gp) == ROOTTASK)
    if ((file=fopen("test.cfg","wb")) == NULL)
    {
      fprintf(stderr,"Error opening file.\n");
      exit(EXIT_FAILURE);
    }

  GP2d_FWriteLatt(p_gp, lattice, file, write_fcn,
     compresscolumn, sizeof(surface), ROOTTASK);
  if (GP2d_GetMyTaskId(p_gp) == ROOTTASK)
    fclose(file);
  exit(EXIT_SUCCESS);
}
```

FORTRAN 90 EXAMPLE

There is a little difference to the C version. While in C it is assumed that the values in the file are readable, this is not so in FORTRAN.

```
include "GP2d.f"

  module TYPES
    type SURFACE
      integer HEIGHT
      integer COLOR
    end type SURFACE
  end module TYPES

  subroutine WRITE_FCN(FILE, BUFFER, BUFSIZE, NELEM)
    use GEOPAR
```

```
  integer BUFSIZE, NELEM
  character, dimension(:) :: BUFFER
  integer FILE
  integer i,j

  do i=0, NELEM-1
    do j=1, BUFSIZE
      write (FILE, ADVANCE='NO') BUFFER(i*BUFSIZE+j)
    end do
  end do
end subroutine WRITE_FCN

subroutine COMPRESSCOLUMN(LP, BUFFER, COLUMN)
  use GEOPAR
  use TYPES

  type (GP2D) LP
  type (SURFACE) COLUMN(LP%LOWCOORDS(2):LP%HIGHCOORDS(2))
  integer BUFFER(0:2*(LP%HIGHCOORDS(2)-LP%LOWCOORDS(2)+1))
  integer i,j

  i=0
  do j=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
    BUFFER(i) = COLUMN(j)%HEIGHT
    i = i + 1
    BUFFER(i) = COLUMN(j)%COLOR
  end do
end subroutine COMPRESSCOLUMN

program FWRITE_LATT
  use GEOPAR
  use TYPES

  type (GP2D) GP
  type (SURFACE), pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, FILE
  type (SURFACE) CELL

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1
```

```
  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 8

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  if (GP%MYTASKID == 0) then
    open (15, FILE='test.cfg', STATUS='REPLACE')
  end if

  CELL%HEIGHT = 100
  CELL%COLOR  = 22
  call GP2DF_FillLatt(GP, ARRAY_PTR, CELL)

  call GP2DF_FWriteLatt(GP, ARRAY_PTR, 15, WRITE_FCN,
     COMPRESSCOLUMN, 8, 0)
  if (GP%MYTASKID == 0) then
    close(15)
  end if
end
```

RELATED INFORMATION

Functions: GP2d_FReadLatt/GP2DF_FReadLatt, GP2d_FStdWriteLatt.

NAME **GP2d_Gather** - Gather lattice.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_Gather(GP2d *gp, void **clattice,
                 const void **lattice, int taskid);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_Gather(GP2d gp, INTEGER clattice,
             INTEGER lattice, INTEGER taskid)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

clattice Pointer to complete lattice.

lattice Pointer to distributed lattice.

taskid task to which lattice is gathered.

DESCRIPTION The function gathers a distributed lattice to one designated task. Only the task with id **task** must allocate storage for the complete lattice.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

clattice Not allocated by GP2d_CreateGlobalLatt/GP2DF_CreateGlobalLatt in task **taskid**.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

taskid Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0] $\times$ GP2d_GetNumProcs(gp)[1] $-$ 1, in C;
- 0 ... gp%NUMPROCS(1) $\times$gp%NUMPROCS(2) $-$ 1, in Fortran 90.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>
#define TASK 0

void initlattice(GP2d *gp,int **lattice)
{
  int x1,x2;
  GP2d_ForAll(gp,x1,x2)
    lattice[x1][x2]=x1*x2;
}

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice, **clattice;
  FILE *file;
  int x1,x2;

  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  initlattice(p_gp, lattice);
  if (GP2d_GetMyTaskId(p_gp) == TASK)
     clattice = (int **) GP2d_CreateGlobalLatt(p_gp);
  GP2d_Gather(p_gp, clattice, lattice, TASK);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program GATHER
use GEOPAR

subroutine INITLATT(LP, LATT)
  use GEOPAR
  type (GP2D) LP
  integer LATT (LP%LOW(2):LP%HIGH(2), LP%LOW(1):LP%HIGH(1))

  integer I, J

  do I=LP%LOWCOORDS(1), LP%HIGHCOORDS(1)-1
```

```
    do J=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
      LATT(J,I) = J*I
    end do
  end do
end subroutine INITLATT

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:), GLOBAL_ARRAY
  integer  IERR, ARRAY_PTR, GLOBAL_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  call INITLATT(GP, ARRAY)
  if (GP%MYTASKID == 0) then
     allocate(GLOBAL_ARRAY(1:GP%INPUTPARAMS%LATTSIZE(2),
                           1:GP%INPUTPARAMS%LATTSIZE(1)))
     call GP2DF_CreateGlobalLatt(GP, GLOBAL_ARRAY, GLOBAL_PTR)
     call GP2DF_Gather(GP, GLOBAL_PTR, ARRAY_PTR, 0)
  end if
end
```

RELATED INFORMATION

Functions: GP2d_CreateGlobalLatt/GP2DF_CreateGlobalLatt, GP2d_Scatter/GP2DF_Scatter.

NAME **GP2d_GetCell** - Get cell.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetCell(GP2d *gp, const void **lattice,
                 int x1, int x2, void *element);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_GetCell(GP2d gp, INTEGER lattice,
              INTEGER x1, INTEGER x2, INTEGER element)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the the distributed lattice.

x1 x_1-coordinate of the lattice element.

x2 x_2-coordinate of the lattice element.

element Pointer to a buffer, to which the contents of the lattice element is copied.

RETURN VALUE TRUE, if the sublattice of the task contains the lattice element, FALSE, if not.

DESCRIPTION This function allows an access to the contents of the whole lattice. The task containing the cell element broadcasts the data to all other tasks. Therefore the GP2d_SetCell/GP2DF_SetCell function is communication intensive, excessive calls to this function decreases performance significantly.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

x1 Not in the range

- $0 \ldots$ GP2d_GetLattSize(gp)[0] $- 1$, in C;
- $0 \ldots$ GP%INPUTPARAMS%LATTSIZE(1) $- 1$, in Fortran.

x2 Not in the range

- $0 \ldots$ GP2d_GetLattSize(gp)[1] $- 1$, in C;
- $0 \ldots$ GP%INPUTPARAMS%LATTSIZE(2) $- 1$, in Fortran.

C EXAMPLE

```
#include <stdio.h>
#include <GP2d.h>

void initlattice(GP2d *gp, int **lattice)
{
  int x1,x2;
  GP2d_ForAll(gp,x1,x2)
    lattice[x1][x2]=x1+x2;
}

void main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int element;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  initlattice(p_gp,lattice);
  GP2d_GetCell(p_gp, lattice, 50, 50, &element);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program GET_CELL
use GEOPAR

subroutine INITLATTICE(LP, LATT)
  use GEOPAR
  type (GP2D) LP
  integer LATT (LP%LOW(2):LP%HIGH(2), LP%LOW(1):LP%HIGH(1))

  integer I, J

  do I=LP%LOWCOORDS(1), LP%HIGHCOORDS(1)-1
    do J=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
      LATT(J,I) = J*I
    end do
  end do
end subroutine INITLATTICE
```

```
  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, ELEMENT

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  call INITLATTICE(GP, ARRAY)
  call GP2DF_GetCell(GP, ARRAY_PTR, 50, 50 ELEMENT)
end
```

RELATED INFORMATION

Functions: GP2d_IsinMyLatt/GP2DF_IsinMyLatt, GP2d_SetCell/GP2DF_SetCell.

NAME **GP2d_Initialize** - Initialization.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_Initialize(GP2d *gp);
```

PARAMETERS

gp Pointer to the struct defining the lattice size, etc.

ret Return value.

RETURN VALUE Returns whether the execution was successful or not.

STRUCTURE

```
typedef struct
{
  int LattSize[2];
  int NumProcs[2];
  int Periods[2];
  int Reorder;
  int *Partition[2];
  int BoundaryWidth[2];
  size_t CellSize;
} GP2d_InputParams;
```

Description of the components:

LattSize Denotes the lattice size in x_1, x_2 direction.

NumProcs Defines the size of the task matrix. The lattice is distributed on a NumProcs[0] $\times$ NumProcs[1] matrix.

Periods If one direction is set true(1), the first and the last cell of the lattice in this direction are neighbours.

Reorder Allows the MPI library to rearrange the underlying processors grid.

Partition Defines the partition of the distributed lattice over the task matrix. If set to NULL, the library will set a balanced distribution.

BoundaryWidth Defines the range of interaction for each x_i-direction. BoundaryWidth[i] cells are shadowed in each task and updated by via a call to GP2d_UpdBnd/GP2DF_UpdBnd.

CellSize Defines the cell size of the lattice.

DESCRIPTION The function initializes the informational structures necessary for the **GeoPar** library. Every **GeoPar** functions uses the pointer gp as its first argument. If the components of the vector **NumProcs** are set to GP2d_COMPUTE, the size of the task matrix will be computed from the number of tasks available.

C EXAMPLE The program defines an int 100×100 lattice distributed on a 2×4 task matrix.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>

int main(void)
{
  GP2d gp;
  GP2d *p_gp = &gp;

  int *partvec[4]={10,40,40,10};
  gp.InputParams.LattSize[0]=100;
  gp.InputParams.LattSize[1]=100;
  gp.InputParams.NumProcs[0]=2;
  gp.InputParams.NumProcs[1]=4;
  gp.InputParams.Periods[0]=1;
  gp.InputParams.Periods[1]=1;
  gp.InputParams.Reorder=0;
  gp.InputParams.Partition[0]=NULL;
  gp.InputParams.Partition[1]=partvec;
  gp.InputParams.BoundaryWidth[0]=1;
  gp.InputParams.BoundaryWidth[1]=1;
  gp.InputParams.CellSize=sizeof(int);

  MPI_Init(NULL,NULL);
  if(!GP2d_Initialize(p_gp))
  {
    fprintf(stderr,"Error initializing lattice.\n");
    exit(EXIT_FAILURE);
  }
  exit(EXIT_SUCCESS);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program INITIALIZE
use GEOPAR
```

```
  type (GP2D) GP
  integer IERR

  GP%INPUTPARAMS%LATTSIZE(1)=100;
  GP%INPUTPARAMS%LATTSIZE(2)=100;
  GP%INPUTPARAMS%NUMPROCS(1)=2;
  GP%INPUTPARAMS%NUMPROCS(2)=4;
  GP%INPUTPARAMS%PERIODS(1)=1;
  GP%INPUTPARAMS%PERIODS(2)=1;
  GP%INPUTPARAMS%REORDER=0;
  GP%INPUTPARAMS%PARTITION(1)=0;
  GP%INPUTPARAMS%PARTITION(2)=0;
  GP%INPUTPARAMS%BOUNDARYWIDTH(1)=1;
  GP%INPUTPARAMS%BOUNDARYWIDTH(2)=1;
  GP%INPUTPARAMS%CELLSIZE=4;

  call MPI_INIT(IERR);
  call GP2DF_Initialize(GP, IERR)
}
```

RELATED INFORMATION

Functions: GP2d_Free/GP2DF_Free

NAME **GP2d_IsinMyLatt** - Test on membership.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_IsinMyLatt(GP2d *gp,int x1,int x2);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_IsinMyLatt(GP2D gp, INTEGER x1,
                 INTEGER x2, INTEGER ret)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

x1 The x_1-coordinate.

x2 The x_2-coordinate.

ret Return value.

RETURN VALUE TRUE,if element (x_1, x_2) is in the local sublattice of the task, FALSE otherwise.

DESCRIPTION Functions tests if element (x_1, x_2) is member of the local sublattice.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

C EXAMPLE The program initializes a lattice to 1, the cell at the center is increase by 1.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define sizex 100
#define sizey 100

int main(void)
{
  GP2d gp = {{sizex,sizey},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
```

```
  int **lattice;
  int element;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  element=1;
  GP2d_FillLatt(p_gp, lattice,&element);
  if (GP2d_IsinMyLatt(p_gp,sizex/2,sizey/2))
     lattice[sizex/2][sizey/2]++;
  exit(EXIT_SUCCESS);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program ISIN_MY_LATT
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, ELEMENT

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  ELEMENT = 1
  call GP2DF_FillLatt(GP, ARRAY_PTR, ELEMENT)
  call GP2DF_IsinMyLatt(GP, 50, 50, IERR)
  if (IERR == 1) then
```

```
    ARRAY(50,50) = ARRAY(50,50) + 1
  end if
end
```

RELATED INFORMATION

Functions: GP2d_GetCell/GP2DF_GetCell, GP2d_SetCell/GP2DF_SetCell.

NAME **GP2d_ReduceData** - Reduce distributed data to local data.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_ReduceData(GP2d *gp, void *OutMsg, void *InMsg,
                     size_t Length, MPI_Datatype Datatype,
                     int Task, MPI_Op Operation);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_ReduceData(GP2D gp, INTEGER OutMsg, INTEGER InMsg,
                 INTEGER Length, INTEGER Datatype,
                 INTEGER Task, INTEGER Operation)
```

PARAMETERS

gp Struct that contains informational parameters.

OutMsg Pointer to the source data.

InMsg Pointer to the result data(i.e. local data of one task).

Length The number of items in the result.

Datatype Type of the operands(to which OutMsg points).

Task The number of the task that gets the result.

Operation The operation that will be performed. Look into your MPI-manual.

DESCRIPTION The function submits the parameters to the corresponding MPI function, which performs a reduce operation on all values to a single value. You may have a look into the reference manual of MPI for information about predefined reduction operations and valid datatypes(*IBM Parallel Environment for AIX: MPI Programming and Subroutine Reference*, 1995).

ERRORS

gp Not initialized with GP2d_Initialize/GP2DF_Initialize.

OutMsg, InMsg Invalid pointers.

Datatype Unknown datatype.

Task Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0]
  $\times$ GP2d_GetNumProcs(gp)[1] $-$ 1, in C;

- 0 . . . gp%NUMPROCS(1) ×gp%NUMPROCS(2) − 1, in Fortran 90.

Operation Unknown operation.

C EXAMPLE

```
#include <GP2d.h>
#include <stdlib.h>
#include <time.h>

#define TASK 0

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  int x1, x2, sum, count;

  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);


  seed((int)time(NULL));
  GP2d_ForAll(p_gp,x1,x2)
  {
    lattice[x1][x2] = random() % 2;
  }

  count = 0;
  GP2d_ForAll(p_gp,x1,x2)
  {
    count += lattice[x1][x2];
  }

  GP2d_ReduceData(p_gp, &count, &sum, 1, MPI_INT, TASK, MPI_SUM);

  if (GP2d_GetMyTaskId(p_gp) == TASK)
  printf("number of initialized cells: %i\n", sum);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"
```

```
program REDUCEDATA
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, X1, X2, count, sum
  real, intent(out) :: value

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  do X1=GP%LOWCOORDS(1), GP%HIGHCOORDS(1)-1
    do X2=GP%LOWCOORDS(2), GP%HIGHCOORDS(2)-1
      call RANDOM_NUMBER(value)
      if (value >= 0.5) then ARRAY(X2,X1)=1 endif
    end do
  end do

  count = 0
  do X1=GP%LOWCOORDS(1), GP%HIGHCOORDS(1)-1
    do X2=GP%LOWCOORDS(2), GP%HIGHCOORDS(2)-1
      count = count + ARRAY(X2,X1)
    end do
  end do

  call GP2DF_ReduceData(GP, count, sum, 1, MPI_INTEGER, 0, MPI_SUM)
```

```
  if (GP%MYTASKID == 0) then
    print *, 'number of initialized cells: ',sum
  end if
end
```

NAME **GP2d_Scatter** - Scatter lattice.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_Scatter(GP2d *gp,void **lattice,const void **clattice,int task);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_Scatter(GP2D gp, INTEGER lattice, INTEGER clattice,
      INTEGER task)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice Pointer to distributed lattice(own sublattice).

clattice Pointer to complete lattice(only for task necessary).

task Task is the owner of the complete lattice.

DESCRIPTION The function scatters a complete lattice from one task to a distributed lattice(each task owns a sublattice).

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

clattice Not allocated by GP2d_CreateGlobalLatt/GP2DF_CreateGlobalLatt in task **task**.

task Not in the range

- 0 ... GP2d_GetNumProcs(gp)[0] $\times$ GP2d_GetNumProcs(gp)[1] $-$ 1, in C;
- 0 ... gp%NUMPROCS(1) $\times$gp%NUMPROCS(2) $-$ 1, in Fortran 90.

C EXAMPLE

```
#include <GP2d.h>
#define TASK 0

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
```

```
          {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
          0,0,0,0,0,{0,0},{0,0},{0,0},
          {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice, **clattice;
  int x1, x2;

  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);

  if(GP2d_GetMyTaskId(p_gp) == TASK)
  {
    clattice=(int **)GP2d_CreateGlobalLatt(p_gp);
    for(x1=0;x1<GP2d_GetLattSize(p_gp)[0];x1++)
      for(x2=0;x2<GP2d_GetLattSize(p_gp)[1];x2++)
         *(clattice[x1]+x2) = x1 + x2;
  }

  GP2d_Scatter(p_gp, lattice, clattice, TASK);
  if(GP2d_GetMyTaskId(p_gp)==TASK)
    GP2d_FreeGlobalLatt(p_gp, clattice);
  GP2d_UpdBnd(gp, lattice);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program SCATTER
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:), CARRAY (:,:)
  integer  IERR, ARRAY_PTR, C_PTR, X1, X2

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
```

```
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)

  if (GP%MYTASKID == 0) then
    allocate(CARRAY(1:GP%INPUTPARAMS%LATTSIZE(2),
         1:GP%INPUTPARAMS%LATTSIZE(1)))
    call GP2DF_CreateGlobalLatt(GP, CARRAY, C_PTR)
    do X1=1, GP%INPUTPARAMS%LATTSIZE(2)
      do X2=1, GP%INPUTPARAMS%LATTSIZE(1)
        CARRAY(X1,X2) = X1 + X2
      end do
    end do
  end if

  GP2DF_Scatter(GP, ARRAY_PTR, C_PTR, 0)

  if (GP%MYTASKID == 0) then
    call GP2DF_FreeGlobalLatt(C_PTR)
  end if

  call GP2DF_UpdBnd(GP, ARRAY_PTR)
end
```

RELATED INFORMATION

Functions: GP2d_CreateCLatt, GP2d_Gather.

NAME **GP2d_SetCell** - Set cell.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_SetCell(GP2d *gp, void **lattice,
                 int x1, int x2, void *cell);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_SetCell(GP2D gp, INTEGER lattice,
              INTEGER x1, INTEGER x2, INTEGER cell,
              INTEGER ret)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the the distributed lattice.

x1 The x_1-coordinate.

x2 The x_2-coordinate.

cell A pointer to the new item written at (x_1, x_2).

ret Return value.

RETURN VALUE TRUE,if element (x_1, x_2) is in the local sublattice of the task, FALSE otherwise.

DESCRIPTION Functions writes a new element into the lattice and is performed on all tasks. Only the task containing the new lattice element is updated. The shadowed boundary elements are not updated.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

x1 Not in the range

- $0 \ldots$ GP2d_GetLattSize(gp)[0] $- 1$, in C;
- $0 \ldots$ gp%INPUTPARAMS%LATTSIZE(1) $- 1$, in Fortran.

x2 Not in the range

- $0 \ldots$ GP2d_GetLattSize(gp)[1] $- 1$, in C;
- $0 \ldots$ gp%INPUTPARAMS%LATTSIZE(2) $- 1$, in Fortran.

cell Not a valid pointer.

C EXAMPLE The program sets the center of the lattice to 1, all other elements are initialized to zero.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define sizex 100
#define sizey 100

int main(void)
{
  GP2d gp = {{sizex,sizey},{2,2}, {True, True}, True,
            {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
            0,0,0,0,0,{0,0},{0,0},{0,0},
            {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  int element;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);
  element=0;
  GP2d_FillLatt(p_gp, lattice, &element);
  GP2d_SetCell(p_gp, lattice, sizex/2, sizey/2, &element);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program SET_CELL
use GEOPAR

  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR, ELEMENT

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%REORDER = 1
```

```
  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, ARRAY_PTR)
  ELEMENT = 0
  call GP2DF_FillLatt(GP, ARRAY_PTR, ELEMENT)
  call GP2DF_SetCell(GP, 50, 50, ELEMENT, IERR)
end
```

RELATED INFORMATION

Functions: GP2d_GetCell/GP2DF_GetCell, GP2d_IsinMyLatt/GP2DF_IsinMyLatt.

NAME **GP2d_UpdBnd** - Update boundaries with periodic boundary conditions.

C SYNOPSIS

```
#include <GP2d.h>
void GP2d_UpdBnd(GP2d *gp, void **lattice);
```

FORTRAN SYNOPSIS

```
include "GP2d.f"
GP2DF_UpdBnd(GP2D gp, INTEGER lattice)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the the distributed lattice.

DESCRIPTION After an update of the lattice the shadowed boundary cells must also be updated.Boundary cells must be interchanged between adjacent tasks. The function performs this update process.

ERRORS

gp Not initialized by GP2d_Initialize/GP2DF_Initialize.

lattice Not allocated by GP2d_CreateLatt/GP2DF_CreateLatt.

C EXAMPLE

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define n 100 /* number of iterations */

void initlattice(GP2d *gp, int **lattice)
{
  int cell;
  cell=0;
  GP2d_FillLatt(gp, lattice, &cell);
  cell=1;
  GP2d_SetCell(gp, lattice, GP2d_GetLattSize(gp)[0]/2,
               GP2d_GetLattSize(gp)[1]/2, &cell);
  GP2d_UpdBnd(gp, lattice);
}

void updatelattice(GP2d *gp, int **lattice)
{
```

```
  int x1,x2;
  GP2d_ForAll(gp,x1,x2)
    lattice[x1][x2]=(lattice[x1+1][x2]+lattice[x1-1][x2]+
                     lattice[x1][x2+1]+lattice[x1][x2-1])/4;
  GP2d_UpdBnd(gp, lattice);
}

int main(void)
{
  GP2d gp = {{100,100},{2,2}, {True, True}, True,
           {NULL,NULL}, {1,1}, sizeof(int), 0, 0,
           0,0,0,0,0,{0,0},{0,0},{0,0},
           {0,0},{0,0},{0,0}};
  GP2d *p_gp = &gp;
  int **lattice;
  int i;
  GP2d_Initialize(p_gp);
  lattice = (int **) GP2d_CreateLatt(p_gp);

  initlattice(gp, lattice);
  for(i=0;i<n;i++)
    updatelattice(gp, lattice);
}
```

FORTRAN 90 EXAMPLE

```
include "GP2d.f"

program UPDBND
use GEOPAR

subroutine INIT_LATTICE(LP, LATT_PTR)
  use GEOPAR
  type (GP2D) LP

  integer IERR, CELL

  CELL = 0
  call GP2DF_FillLatt(LP, LATT_PTR, CELL)
  CELL = 1
  call GP2DF_SetCell(LP, LATT_PTR, 50, 50, CELL, IERR)
  call GP2DF_UpdBnd(LP, LATT_PTR)
end subroutine INIT_LATTICE

subroutine UPDATE_LATTICE(LP, LATT, LATT_PTR)
  use GEOPAR
  type (GP2D) LP
```

```
  integer LATT (LP%LOW(2):LP%HIGH(2), LP%LOW(1):LP%HIGH(1))

  integer I, J

  do I=LP%LOWCOORDS(1), LP%HIGHCOORDS(1)-1
    do J=LP%LOWCOORDS(2), LP%HIGHCOORDS(2)-1
      LATT(J,I) = (LATT(J-1,I) + LATT(J+1,I) +
                   LATT(J,I-1) + LATT(J,I+1))/4
    end do
  end do
  call GP2DF_UpdBnd(LP, LATT_PTR)
end subroutine UPDATE_LATTICE


  type (GP2D) GP
  integer, pointer :: ARRAY (:,:)
  integer  IERR, ARRAY_PTR

  GP%INPUTPARAMS%LATTSIZE(1) = 100
  GP%INPUTPARAMS%LATTSIZE(2) = 100

  GP%INPUTPARAMS%BOUNDARYWIDTH(1) = 1
  GP%INPUTPARAMS%BOUNDARYWIDTH(2) = 1

  GP%INPUTPARAMS%NUMPROCS(1) = 2
  GP%INPUTPARAMS%NUMPROCS(2) = 2

  GP%INPUTPARAMS%REORDER = 1

  GP%INPUTPARAMS%PERIODS(1) = 1
  GP%INPUTPARAMS%PERIODS(2) = 1

  GP%INPUTPARAMS%CELLSIZE = 4

  call MPI_INIT(IERR)
  call GP2DF_Initialize(GP, IERR)

  allocate(ARRAY(GP%LOW(2):GP%HIGH(2), GP%LOW(1):GP%HIGH(1)))
  call GP2DF_CreateLatt(GP, ARRAY, PTR)
  call INIT_LATTICE(GP, ARRAY_PTR)
  do I=1, 100
    call UPDATE_LATTICE(GP, ARRAY, ARRAY_PTR)
  end do
end
```

3.2 Macros listed alphabetically

Function	Page	Description
GP2d_ForAll	75	Iterator over whole sublattice
GP2d_FStdReadLatt	76	Read lattice from file
GP2d_FStdWriteLatt	78	Write lattice to file
GP2d_GetBoundaryWidth	80	Get width of boundaries
GP2d_GetCellSize	81	Get size of cell element
GP2d_GetHighCoordX1	82	Get upper boundary of sublattice
GP2d_GetHighCoordX2	83	Get upper boundary of sublattice
GP2d_GetLattSize	84	Get size of global lattice
GP2d_GetLowCoordX1	85	Get lower bound of sublattice
GP2d_GetLowCoordX2	86	Get lower bound of sublattice

NAME **GP2d_ForAll** - Iterator over whole sublattice.

C SYNOPSIS

```
#include <GP2d.h>
#define GP2d_ForAll(gp,x1,x2) \
  for(x1=GP2d_GetLowCoordX1(gp);x1<GP2d_GetHighCoordX1(gp);x1++) \
    for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

x1 int index.

x2 int index.

DESCRIPTION This macro defines similar to the for statement in C an iterator over the 2-dimensional sublattice.

EXAMPLES The program fills lattice with value '2'.

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d_InputParams params={{10,10},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  int **lattice;
  int x1,x2;
  gp=GP2d_Initialize(params);
  lattice=(int **)GP2d_CreateLatt(gp);
  GP2d_ForAll(gp,x1,x2)
     lattice[x1][x2]=2;
  GP2d_UpdBndPbc(gp,lattice);
}
```

NAME **GP2d_FStdReadLatt** - Read lattice from a file. Simply read distributed lattice from file and distribute

C SYNOPSIS

```
#include <stdio.h>
#include <GP2d.h>
#define GP2d_FStdReadLatt(gp,lattice,file,sourcetask) \
         GP2d_FReadLatt(lattice,file,GP2d_StdRead,0,sourcetask)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the distributed lattice.

file The file descriptor the data is read.

sourcetask The task identifier of the task, that reads the file and distributes the data to all other tasks.

DESCRIPTION The function allows the restoring of a lattice configuration from one file. The boundary cells of the sublattices are not updated.

ERRORS

gp Not initialized by GP2d_Initialize.

lattice Not allocated by GP2d_CreateLatt.

file Invalid file pointer.

sourcetask Not in the range $0 \ldots$ GP2d_GetNumProcs(gp)[0] $/ * changetoMPI!!! * / \times$ GP2d_GetNumProcs(gp)[1] $- 1$. /* change to MPI!!! */

Program reads the contents of the lattice from a file.

EXAMPLES

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0
int main(void)
{
  GP2d_InputParams Params={{100,100},{2,2},{NULL,NULL},{1,1},sizeof(float)};
  GP2d *gp;
  FILE *file;
  float **lattice;
```

```
  gp=GP2d_Initialize(Params);
  lattice=(float **)GP2d_CreateLatt(gp);
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    if((file=fopen("test.cfg","rb"))==NULL)
    {
      fprintf(stderr,"Error opening file.\n");
      exit(EXIT_FAILURE);
    }
  GP2d_FStdReadLatt(gp,lattice,file,ROOTTASK);
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    fclose(file);
  GP2d_UpdBndPbc(gp,lattice);
  exit(EXIT_SUCCESS);
}
```

RELATED INFORMATION

Functions: GP2d_FReadLatt, GP2d_FWriteLatt.

NAME **GP2d_FStdWriteLatt** - Write lattice to a file. Simply collect and write distributed lattice to file

C SYNOPSIS

```
#include <stdio.h>
#include <GP2d.h>
#define GP2d_FStdWriteLatt(lattice,file,desttask) \
          GP2d_FWriteLatt(lattice,file,GP2d_StdWrite,0,desttask)
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

lattice The pointer to the distributed lattice.

file The file descriptor the data is written.

desttask The task identifier of the task, that collects the data and writes the file.

DESCRIPTION The function allows the storing of a lattice configuration to one file.

ERRORS

gp Not initialized by GP2d_Initialize.

lattice Not allocated by GP2d_CreateLatt.

file Invalid file pointer.

desttask Not in the range $0 \ldots$ GP2d_GetNumProcs(gp)[0] $/ * changetoMPI!!! * /$ $\times$ GP2d_GetNumProcs(gp)[1] $- 1$. /* change to MPI!!! */

EXAMPLES The program stores a float value lattice into a file.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0
int main(void)
{
  GP2d_InputParams Params={{100,100},{2,2},{NULL,NULL},{1,1},sizeof(float)};
  GP2d *gp;
  FILE *file;
  float **lattice;
  float cell=4.0;
```

```
  if((gp=GP2d_Initialize(Params))==NULL)
  {
    fprintf(stderr,"Error initializing lattice.\n");
    exit(EXIT_FAILURE);
  }
  lattice=(float **)GP2d_CreateLatt(gp);
  GP2d_InitLatt(gp,lattice,&cell);
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    if((file=fopen("test.cfg","wb"))==NULL)
    {
      fprintf(stderr,"Error opening file.\n");
      exit(EXIT_FAILURE);
    }
  GP2d_FStdWriteLatt(gp,lattice,file,ROOTTASK);
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    fclose(file);
  exit(EXIT_SUCCESS);
}
```

RELATED INFORMATION

Functions: GP2d_FReadLatt, GP2d_FWriteLatt.

NAME **GP2d_GetBoundaryWidth** - Get width of boundary.

C SYNOPSIS

```
#include <GP2d.h>
int* GP2d_GetBoundaryWidth(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE A pointer to an array containing the boundary width.

DESCRIPTION The functions returns a pointer to an array storing information about the boundary width for each space dimension.

NOTES This function is defined as a macro.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES Program writes boundary widths on stdout.

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0
int main(void)
{
  GP2d_InputParams params={{100,100},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  if((gp=GP2d_Initialize(params))==NULL)
  {
    fprintf(stderr,"Error initializing lattice\n";
    exit(EXIT_FAILURE);
  }
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    printf("Boundary width in x1: %d\n"
           "Boundary width in x2: %d\n",
           GP2d_GetBoundaryWidth(gp)[0],
           GP2d_GetBoundaryWidth(gp)[1]);
  exit(EXIT_SUCCESS);
}
```

NAME **GP2d_GetCellSize** - Get cell size.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetCellSize(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE Size of one cell element.

DESCRIPTION Function returns the size of one cell element in bytes.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES Program prints on stdout the size of lattice element.

```
#include <stdio.h>
#include <GP2d.h>
typedef struct
{
  int count;
  double coord[3];
}CELL_T;
int main(void)
{
  GP2d_InputParams params={{20,20},{2,2},{NULL,NULL},{1,1},sizeof(CELL_T)};
  GP2d *gp;
  gp=GP2d_Initialize(params);
  if(GP2d_GetMyTaskId(gp)==0) /* change to MPI!!! */
    printf("Size(cell)=%d Bytes.\n",GP2d_GetCellSize(gp));
}
```

NAME **GP2d_GetHighCoordX1** - Get upper boundary of sublattice.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetHighCoordX1(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE The upper bound in x_1-direction of the sublattice.

DESCRIPTION The function returns the upper bound index of the local sublattice in x_1-direction.

NOTES The function is implemented as a macro due to performance reasons.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES The program fills the lattice with the sum of the cells coordinates.

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d_InputParams params={{10,10},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  int **lattice;
  int x1,x2;
  gp=GP2d_Initialize(params);
  lattice=(int **)GP2d_CreateLatt(gp);
  for(x1=GP2d_GetLowCoordX1(gp);x1<GP2d_GetHighCoordX1(gp);x1++)
    for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
      lattice[x1][x2]=x1+x2;
  GP2d_UpdBndPbc(gp,lattice);
}
```

RELATED INFORMATION

Functions: GP2d_ForAll, GP2d_GetHighCoordX2, GP2d_GetLowCoordX1, GP2d_GetLowCoordX2.

NAME **GP2d_GetHighCoordX2** - Get upper bound of sublattice.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetHighCoordX2(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE The upper bound in x_2-direction of the sublattice.

DESCRIPTION The function returns the upper bound index of the local sublattice in x_2-direction.

NOTES The function is implemented as a macro due to performance reasons.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d_InputParams params={{10,10},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  int **lattice;
  int x,y;
  gp=GP2d_Initialize(params);
  gp=(int **)GP2d_CreateLatt(gp);
  for(x=GP2d_GetLowCoordX1(gp);x<GP2d_GetHighCoordX1(gp);x++)
    for(y=GP2d_GetLowCoordX2(gp);y<GP2d_GetLowCoordX2(gp);y++)
      lattice[x][y]=x+y;
  GP2d_UpdBndPbc(gp,lattice);
}
```

RELATED INFORMATION

Functions: GP2d_ForAll, GP2d_GetHighCoordX2, GP2d_GetLowCoordX1, GP2d_GetLowCoordX2.

NAME **GP2d_GetLattSize** - Get size of lattice.

C SYNOPSIS

```
#include <GP2d.h>
int* GP2d_GetLattSize(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE A pointer to an array containing the lattice sizes.

DESCRIPTION The functions returns a pointer to an array storing information about the lattice size for each space dimension.

NOTES This function is defined as a macro.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES

```
#include <stdlib.h>
#include <stdio.h>
#include <GP2d.h>
#define ROOTTASK 0
int main(void)
{
  GP2d_InputParams params={{100,100},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  if((gp=GP2d_Initialize(params))==NULL)
  {
    fprintf(stderr,"Error initializing lattice\n";
    exit(EXIT_FAILURE);
  }
  if(GP2d_GetMyTaskId(gp)==ROOTTASK) /* change to MPI!!! */
    printf("Lattice size in x1: %d\n"
           "Lattice size in x2: %d\n",
           GP2d_GetLattSize(gp)[0],
           GP2d_GetLattSize(gp)[1]);
  exit(EXIT_SUCCESS);
}
```

NAME **GP2d_GetLowCoordX1** - Get lower boundary of sublattice.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetLowCoordX1(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE The lower bound in x_1-direction of the sublattice.

DESCRIPTION The function returns the lower bound index of the local sublattice in x_1-direction.

NOTES The function is implemented as a macro due to performance reasons.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES The program fills the lattice with the sum of the cells coordinates.

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d_InputParams params={{10,10},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  int **lattice;
  int x1,x2;
  gp=GP2d_Initialize(params);
  lattice=(int **)GP2d_CreateLatt(gp);
  for(x1=GP2d_GetLowCoordX1(gp);x1<GP2d_GetHighCoordX1(gp);x1++)
    for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
      lattice[x1][x2]=x1+x2;
  GP2d_UpdBndPbc(gp,lattice);
}
```

RELATED INFORMATION

Functions: GP2d_ForAll, GP2d_GetHighCoordX1, GP2d_GetHighCoordX2, GP2d_GetLowCoordX2.

NAME **GP2d_GetLowCoordX2** - Get lower boundary of sublattice.

C SYNOPSIS

```
#include <GP2d.h>
int GP2d_GetLowCoordX2(GP2d *gp);
```

PARAMETERS

gp The pointer to the struct containing informational parameters.

RETURN VALUE The lower bound in x_2-direction of the sublattice.

DESCRIPTION The function returns the lower bound index of the local sublattice in x_2-direction.

NOTES The function is implemented as a macro due to performance reasons.

ERRORS

gp Not initialized by GP2d_Initialize.

EXAMPLES The program fills the lattice with the sum of the cells coordinates.

```
#include <stdio.h>
#include <GP2d.h>
void main(void)
{
  GP2d_InputParams params={{10,10},{2,2},{NULL,NULL},{1,1},sizeof(int)};
  GP2d *gp;
  int **lattice;
  int x1,x2;
  gp=GP2d_Initialize(params);
  lattice=(int **)GP2d_CreateLatt(gp);
  for(x1=GP2d_GetLowCoordX1(gp);x1<GP2d_GetHighCoordX1(gp);x1++)
    for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
      lattice[x1][x2]=x1+x2;
  GP2d_UpdBndPbc(gp,lattice);
}
```

RELATED INFORMATION

Functions: GP2d_ForAll, GP2d_GetHighCoordX1, GP2d_GetHighCoordX2, GP2d_GetLowCoordX1.

4 Appendix

```
/*****************************************************************************/
/**                                                                         **/
/**                          g   o   l   .   c                              **/
/**                                                                         **/
/**                         GAME OF LIFE  (John Conway)                     **/
/**                                                                         **/
/** Application program for the GEOPAR function library for geometrical     **/
/** parallelization. It implements a simple cellular automaton.             **/
/**                                                                         **/
/*****************************************************************************/

#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
#include "GP2d.h"    /* Including prototypes and macros for GEOPAR */
#define uSecScale       1.0e-6      /* Microsecond conversions */
#define LATTSIZE 400  /* Lattice size */
#define FILENAME "gol.cfg" /* Filename of  configuration */
#define ROOTTASK 0 /* Task identifier, which performs I/O operations */

typedef enum {DEAD=0, ALIVE=1} STATE; /* Type definition for lattice */
                                      /* elements                    */
double mrun(void)
{
  double  ret;
  struct timeval tp;
  struct timezone tzp;
  gettimeofday(&tp,&tzp);
  ret = (((double)tp.tv_usec) * uSecScale) + (double)tp.tv_sec;
  return                 ret;
}

void initgol(GP2d *gp,STATE **ca)
/*****************************************************************************/
/**                                                                         **/
/**                     i  n  i  t  g  o  l                                 **/
/**  sets initial state of the cellular automaton.                          **/
/**                                                                         **/
/*****************************************************************************/

{
  int x1,x2;
  STATE cell;
  cell=DEAD;

  srand48(189128+GP2d_GetMyTaskId(gp));
  GP2d_ForAll(gp,x1,x2)
```

```
    ca[x1][x2]=(drand48()<0.3) ? ALIVE : DEAD; /* random placement of cells */

  GP2d_UpdBnd(gp, (void **)ca); /* Update the boundary cell with periodic */
                                /* boundary conditions                   */
} /* of 'initgol' */

void updategol(GP2d *gp,STATE **caold, STATE **canew)
/*************************************************************************/
/**                                                                     **/
/**                    u p d a t e g o l                                **/
/**  function performs an update of lattice according to the rules of the  **/
/**  "game of life" using an auxiliary lattice.                         **/
/**                                                                     **/
/*************************************************************************/
{
  int x1,x2,count;

  GP2d_ForAll(gp,x1,x2) /* Iterator over whole sublattice */
  {
    count=caold[x1-1][x2-1]+
          caold[x1][x2-1]+
          caold[x1+1][x2-1]+
          caold[x1-1][x2]+
          caold[x1+1][x2]+
          caold[x1-1][x2+1]+
          caold[x1][x2+1]+
          caold[x1+1][x2+1];
    /* Counting "living" neighbors of cell(x,y) */
    if(caold[x1][x2]==ALIVE)
      canew[x1][x2]=(count==2 || count==3) ? ALIVE : DEAD;
    else
      canew[x1][x2]=(count==3) ? ALIVE : DEAD;
  }

  GP2d_CopyLatt(gp,(void **)caold,(void **)canew);
  GP2d_UpdBnd(gp,(void **)caold);  /* update periodic boundaries */

} /* of 'updategol' */

void compresscolumn(GP2d *gp,char *buffer,const STATE *column)
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
    *buffer++=column[x2];
} /* of 'compresscolumn' */

void readGol(GP2d *gp, STATE *column, char *buffer)
```

```
{
  int x2;
  for(x2=GP2d_GetLowCoordX2(gp);x2<GP2d_GetHighCoordX2(gp);x2++)
     column[x2]=*buffer++;
}

void writegol(GP2d *gp,STATE **ca,FILE *file)
{
  GP2d_FWriteLatt(gp, (void **) ca, file, (GP2d_IOFunction) GP2d_DEFAULT,
     (GP2d_TransferFunction) compresscolumn, 1,
                 ROOTTASK);
} /* of 'writegol' */

int countgol(GP2d *gp,STATE **ca)
/*****************************************************************************/
/**                                                                         **/
/**               c  o  u  n  t  g  o  l                                    **/
/** Function counts the number of living cells of the the distributed       **/
/** lattice. The result of the global operation is returned in  the         **/
/** ROOTTASK.                                                               **/
/**                                                                         **/
/*****************************************************************************/
{
  int x1,x2,count,global_count;
  count=0;
  GP2d_ForAll(gp,x1,x2)
    count+=ca[x1][x2];
  GP2d_ReduceData(gp, &count, &global_count, 1, MPI_INTEGER, ROOTTASK,
MPI_SUM);
/*  fprintf(stderr, "%d MPI_SUM, %d MPI_INT\n", MPI_SUM, MPI_INTEGER);*/
#ifdef DEBUG
  fprintf(stderr, "finished ReduceData at task %d\n",
GP2d_GetMyTaskId(gp));
#endif
  return global_count;
} /* of 'countgol' */

void printcolumn(GP2d *gp,void *data, int x1,STATE *column)
{
  int x2;
  printf("%3d ",x1);
  for(x2=0;x2<GP2d_GetLattSize(gp)[1];x2++)
    printf(column[x2]==ALIVE ? "*" : ".");
  printf("\n");
} /* of 'printcolumn' */

void printgol(GP2d *gp,STATE **ca,int iter)
```

```
{
  if(GP2d_GetMyTaskId(gp)==ROOTTASK)
    printf("Iteration: %d\n",iter);

  GP2d_Collect(gp,0,(void **)ca,(GP2d_CollectFunction)printcolumn,ROOTTASK);

  if(GP2d_GetMyTaskId(gp)==ROOTTASK)
    printf("\n");

} /* of 'printgol' */

void printSubLatt(GP2d *gp, int **ca)
{
  int x, y;

  for(x=GP2d_GetLowCoordX1(gp)-GP2d_GetBoundaryWidth(gp)[0];
      x<GP2d_GetHighCoordX1(gp)+GP2d_GetBoundaryWidth(gp)[0];x++)
  {
     printf("%d%d | ", GP2d_GetMyTaskId(gp), x);
     for(y=GP2d_GetLowCoordX2(gp)-GP2d_GetBoundaryWidth(gp)[1];
         y<GP2d_GetHighCoordX2(gp)+GP2d_GetBoundaryWidth(gp)[1];y++)
     {
printf(ca[x][y] == ALIVE ? "*" : ".");
     }
     printf("\n");
  }
  printf("\n");
} /* end of 'printSubLatt' */

int main(int argc,char **argv)
{
  GP2d *gp;

  struct
  {
    int n,step,size;
  } header;

  STATE **ca, **canew; /* Pointer to lattice */
  FILE *cfg; /* Output file for configurations */
  FILE *in;
  int i,count;
  double t1,t2;

  gp = (GP2d *) malloc(sizeof(GP2d));

  if (argc >= 7)
```

```
{
   sscanf(argv[5], "%d", &gp->InputParams.LattSize[0]);
   sscanf(argv[6], "%d", &gp->InputParams.LattSize[1]);
}

gp->InputParams.BoundaryWidth[0]=gp->InputParams.BoundaryWidth[1]=1;
gp->InputParams.Reorder = TRUE;
gp->InputParams.Periods[0] = TRUE;
gp->InputParams.Periods[1] = TRUE;
gp->InputParams.Partition[0]=gp->InputParams.Partition[1]=NULL;
gp->InputParams.CellSize=sizeof(STATE); /* Size of lattice element */
gp->InputParams.Communicator=MPI_COMM_WORLD;

if (argc >= 5)
{
   sscanf(argv[3], "%d", &gp->InputParams.NumProcs[0]);
   sscanf(argv[4], "%d", &gp->InputParams.NumProcs[1]);
}
MPI_Init(&argc, &argv);

GP2d_Initialize(gp);
if(gp==NULL)
{
  fprintf(stderr,"Error allocating processors, program terminated.\n");
  return 1;
}

ca=(STATE **)GP2d_CreateLatt(gp, NULL);
canew=(STATE **)GP2d_CreateLatt(gp, NULL);

if(GP2d_GetMyTaskId(gp)==ROOTTASK)
{
  in=fopen("Cin2.dat","r");
  fread(&header, sizeof(header), 1, in);
  sscanf(argv[1],"%d",&header.n);
  sscanf(argv[2],"%d",&header.step);
  header.size = GP2d_GetLattSize(gp)[0];

  if(header.step)
  { /* Write header for configuration file */
    if((cfg=fopen(FILENAME,"wb"))==NULL)
    {
      fprintf(stderr,"Error creating file '%s'.\n",FILENAME);
      return 2;
    }
    fwrite(&header,sizeof(header),1,cfg);
  }
```

```
  }

  /* Distribute parameters to all tasks */
  GP2d_BCastData(gp,&header,sizeof(header),ROOTTASK);

  /* Set initial state of cellular automaton */
  /* initgol(gp, ca); */
  GP2d_FReadLatt(gp, ca, in, (GP2d_IOFunction) GP2d_DEFAULT,
    (GP2d_TransferFunction) readGol, 1, 0);
  GP2d_UpdBnd(gp, ca);
  t1=mrun();
  if (GP2d_GetMyTaskId(gp) == ROOTTASK )
     fclose(in);

  for(i=1;i<=header.n;i++)
  {
    updategol(gp, ca, canew); /* Update cellular automaton */
    if(header.step && ((i % header.step) == 0))
    {
      printgol(gp,ca,i);
      count=countgol(gp,ca); /* Count number of "living" */
                             /* cells                    */
      writegol(gp,ca,cfg); /* Write configuration of CA into file */
      if(GP2d_GetMyTaskId(gp)==ROOTTASK)
        fprintf(stderr,"i=%d,count=%d\n",i,count);
    }
  }
  if(GP2d_GetMyTaskId(gp)==ROOTTASK)
  {
    t2=mrun();
    printf("Time= %.3f sec.\n",t2-t1);
  }
  if(header.step && GP2d_GetMyTaskId(gp)==ROOTTASK)
    fclose(cfg);
  return 0;
} /* of 'main' */
```