

Parallel Programming Laboratory
University of Illinois at Urbana-Champaign

CHARM++
NetFEM
Manual

The initial version of CHARM++ NetFEM Framework was developed by Orion Lawlor in 2001.

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1 Introduction

NetFEM was built to provide an easy way to visualize the current state of a finite-element simulation, or any parallel program that computes on an unstructured mesh. NetFEM is designed to require very little effort to add to a program, and connects to the running program over the network via the network protocol CCS (Converse Client/Server).

2 Compiling and Installing

NetFEM is part of CHARM++, so it can be downloaded as part of charm. To build NetFEM, just build FEM normally, or else do a make in charm/net-linux/tmp/libs/ck-libs/netfem/.

To link with NetFEM, add `-module netfem` to your program's link line. Note that you do *not* need to use the FEM framework to use NetFEM.

The netfem header file for C is called "netfem.h", the header for fortran is called 'netfem.f'. A simple example NetFEM program is in charm/pgms/charm++/fem/simple2D/. A more complicated example is in charm/pgms/charm++/fem/crack2D/.

3 Running NetFEM Online

Once you have a NetFEM program, you can run it and view the results online by starting the program with CCS enabled:

```
foo.bar.edu> ./charmrun ./myprogram +p2 ++server ++server-port 1234
```

"++server-port" controls the TCP port number to use for CCS—here, we use 1234. Currently, NetFEM only works with one chunk per processor—that is, the `-vp` option cannot be used.

To view the results online, you then start the NetFEM client, which can be downloaded for Linux or Windows from

```
http://charm.cs.uiuc.edu/research/fem/netfem/
```

Enter the name of the machine running charmrun and the TCP port number into the NetFEM client—for example, you might run:

```
netfem foo.bar.edu:1234
```

The NetFEM client will then connect to the program, download the most recent mesh registered with NetFEM.POINTAT, and display it. At any time, you can press the "update" button to reload the latest mesh.

4 Running NetFEM Offline

Rather than using CCS as above, you can register your meshes using NetFEM.WRITE, which makes the server write out binary output dump files. For example, to view timestep 10, which is written to the "NetFEM/10/" directory, you'd run the client program as:

```
netfem NetFEM/10
```

In offline mode, the "update" button fetches the next extant timestep directory.

5 NetFEM with other Visualization Tools

You can use a provided converter program to convert the offline NetFEM files into an XML format compatible with the powerful offline visualization tool ParaView(<http://paraview.org>). The converter is located in `.../charm/src/libs/ck-libs/netfem/ParaviewConverter/`. Build the converter by simply issuing a “make” command in that directory(assuming NetFEM already has been built).

Run the converter from the parent directory of the “NetFEM” directory to be converted. The converter will generate a directory called “ParaViewData”, which contains subdirectories for each timestep, along with a “timestep” directory for index files for each timestep. All files in the ParaViewData directory can be opened by ParaView. To open all chunks for a given timestep, open the desired timestep file in “ParaView-Data/timesteps”. Also, individual partition files can also be opened from “ParaViewData / <timestep> / <partition_num>”.

6 Interface Basics

You publish your data via NetFEM by making a series of calls to describe the current state of your data. There are only 6 possible calls you can make.

`NetFEM_Begin` is the first routine you call. `NetFEM_End` is the last routine to call. These two calls bracket all the other NetFEM calls.

`NetFEM_Nodes` describes the properties of the nodes, or vertices of the domain. `NetFEM_Elements` describes the properties of your elements (triangles, tetrahedra, etc.). After making one of these calls, you list the different data arrays associated with your nodes or elements by making calls to `NetFEM_Scalar` or `NetFEM_Vector`.

For example, a typical finite element simulation might have a scalar mass and vector position, velocity, and net force associated with each node; and have a scalar stress value associated with each element. The sequence of NetFEM calls this application would make would be:

```
NetFEM_Begin
NetFEM_Nodes -- lists position of each node
NetFEM_Vector -- lists velocity of each node
NetFEM_Vector -- lists net force on each node
NetFEM_Scalar -- lists mass of each node

NetFEM_Elements -- lists the nodes of each element
NetFEM_Scalar -- lists the stress of each element

NetFEM_End
```

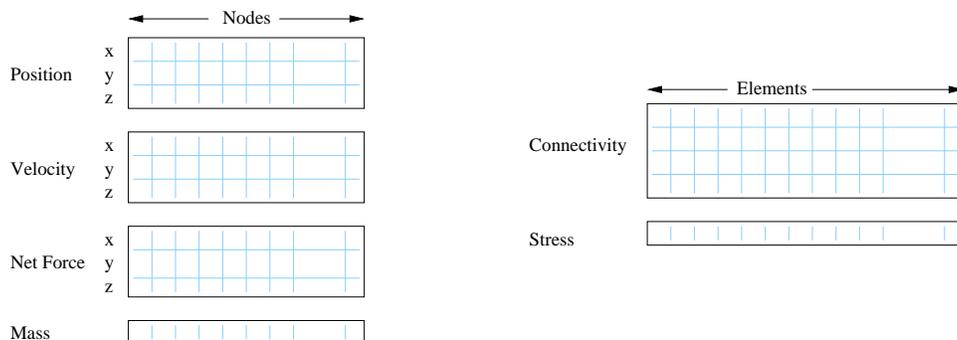


Figure 1: These arrays, typical of a finite element analysis program, might be passed into NetFEM.

7 Simple Interface

The details of how to make each call are:

```
NetFEM NetFEM_Begin(int source, int step, int dim, int flavor);
integer function NetFEM_Begin(source,step,dim,flavor)
    integer, intent(in) :: source,step,dim,flavor
```

Begins describing a single piece of a mesh. Returns a handle that is used for each subsequent call until `NetFEM_End`. This call, like all `NetFEM` calls, is collective—every processor should make the same calls in the same order.

source identifies the piece of the mesh—use `FEM_My_partition` or `CkMyPe`.

step identifies which version of the mesh this is—for example, you might use the timestep number. This is only used to identify the mesh in the client.

dim is the number of spatial dimensions. For example, in a 2D computation, you'd pass `dim==2`; in a 3D computation, `dim==3`. The client currently only supports 2D or 3D computations.

flavor specifies what to do with the data. This can take the value `NetFEM_POINTAT`, which is used in online visualization, and specifies that `NetFEM` should only keep a pointer to your data rather than copy it out of your arrays. Or it can take the value `NetFEM_WRITE`, which writes out the data to files named “`NetFEM/step/source.dat`” for offline visualization.

```
void NetFEM_End(NetFEM n);
subroutine NetFEM_End(n)
    integer, intent(in) :: n
```

Finishes describing a single piece of a mesh, which then makes the mesh available for display.

```
void NetFEM_Nodes(NetFEM n,int nNodes,const double *loc,const char *name);
subroutine NetFEM_Nodes(n,nNodes,loc,name)
    integer, intent(in) :: n, nNodes
    double precision, intent(in) :: loc(dim,nNodes)
    character*(*), intent(in) :: name
```

Describes the nodes in this piece of the mesh.

n is the `NetFEM` handle obtained from `NetFEM_Begin`.

nNodes is the number of nodes listed here.

loc is the location of each node. This must be double-precision array, laid out with the same number of dimensions as passed to `NetFEM_Begin`. For example, in C the location of a 2D node *n* is stored in `loc[2*n+0]` (x coordinate) and `loc[2*n+1]` (y coordinate). In Fortran, location of a node *n* is stored in `loc(:,n)`.

name is a human-readable name for the node locations to display in the client. We recommend also including the location units here, for example “Position (m)”.

```
void NetFEM_Elements(NetFEM n,int nElements,int nodePerEl,const int *conn,const char *name);
subroutine NetFEM_Elements(n,nElements,nodePerEl,conn,name)
    integer, intent(in) :: n, nElements, nodePerEl
    integer, intent(in) :: conn(nodePerEl,nElements)
    character*(*), intent(in) :: name
```

Describes the elements in this piece of the mesh. Unlike `NetFEM_Nodes`, this call can be repeated if there are different types of elements (For example, some meshes contain a mix of triangles and quadrilaterals).

n is the `NetFEM` handle obtained from `NetFEM_Begin`.

nElements is the number of elements listed here.

nodePerEl is the number of nodes for each element. For example, a triangle has 3 nodes per element; while tetrahedra have 4.

conn gives the index of each element's nodes. Note that when called from C, the first node is listed in *conn* as 0 (0-based node indexing), and element *e*'s first node is stored in *conn*[*e***nodePerEl*+0]. When called from Fortran, the first node is listed as 1 (1-based node indexing), and element *e*'s first node is stored in *conn*(1,*e*) or *conn*((*e*-1)**nodePerEl*+1).

name is a human-readable name for the elements to display in the client. For example, this might be "Linear-Strain Triangles".

```
void NetFEM_Vector(NetFEM n,const double *data,const char *name);
subroutine NetFEM_Vector(n,data,name)
    integer, intent(in) :: n
    double precision, intent(in) :: data(dim,lastEntity)
    character*(*), intent(in) :: name
```

Describes a spatial vector associated with each node or element in the mesh. Attaches the vector to the most recently listed node or element. You can repeat this call several times to describe different vectors.

n is the NetFEM handle obtained from *NetFEM_Begin*.

data is the double-precision array of vector values. The dimensions of the array have to match up with the node or element the data is associated with—in C, a 2D element *e*'s vector starts at *data*[2**e*]; in Fortran, element *e*'s vector is *data*(:,*e*).

name is a human-readable name for this vector data. For example, this might be "Velocity (m/s)".

```
void NetFEM_Scalar(NetFEM n,const double *data,int dataPer,const char *name);
subroutine NetFEM_Scalar(n,data,dataPer,name)
    integer, intent(in) :: n, dataPer
    double precision, intent(in) :: data(dataPer,lastEntity)
    character*(*), intent(in) :: name
```

Describes some scalar data associated with each node or element in the mesh. Like *NetFEM_Vector*, this data is attached to the most recently listed node or element and this call can be repeated. For a node or element, you can make the calls to *NetFEM_Vector* and *NetFEM_Scalar* in any order.

n is the NetFEM handle obtained from *NetFEM_Begin*.

data is the double-precision array of values. In C, an element *e*'s scalar values start at *data*[*dataPer***e*]; in Fortran, element *e*'s values are in *data*(:,*e*).

dataPer is the number of values associated with each node or element. For true scalar data, this is 1; but can be any value. Even if *dataPer* happens to equal the number of dimensions, the client knows that this data does not represent a spatial vector.

name is a human-readable name for this scalar data. For example, this might be "Mass (Kg)" or "Stresses (pure)".

8 Advanced "Field" Interface

This more advanced interface can be used if you store your node or element data in arrays of C structs or Fortran *TYPE*s. To use this interface, you'll have to provide the name of your struct and field. Each "field" routine is just an extended version of a regular NetFEM call described above, and can be used in place of the regular NetFEM call. In each case, you pass a description of your field in addition to the usual NetFEM parameters.

In C, use the macro "*NetFEM_Field*(*theStruct*,*theField*)" to describe the *FIELD*. For example, to describe the field "loc" of your structure named "node_t",

```
node_t *myNodes=...;
..., NetFEM_Field(node_t,loc), ...
```

In Fortran, you must pass as FIELD the byte offset from the start of the structure to the start of the field, then the size of the structure. The FEM "offsetof" routine, which returns the number of bytes between its arguments, can be used for this. For example, to describe the field "loc" of your named type "NODE",

```
TYPE(NODE), ALLOCATABLE :: n(:)
..., offsetof(n(1),n(1)%loc),offsetof(n(1),n(2)), ...
```

```
void NetFEM_Nodes_field(NetFEM n,int nNodes,FIELD,const void *loc,const char *name);
subroutine NetFEM_Nodes_field(n,nNodes,FIELD,loc,name)
```

A FIELD version of NetFEM_Nodes.

```
void NetFEM_Elements_field(NetFEM n,int nElements,int nodePerEl,FIELD,int idxBase,const int *conn,const char
*name);
subroutine NetFEM_Elements_field(n,nElements,nodePerEl,FIELD,idxBase,conn,name)
```

A FIELD version of NetFEM_Elements. This version also allows you to control the starting node index of the connectivity array—in C, this is normally 0; in Fortran, this is normally 1.

```
void NetFEM_Vector_field(NetFEM n,const double *data,FIELD,const char *name);
subroutine NetFEM_Vector_field(n,data,FIELD,name)
```

A FIELD version of NetFEM_Vector.

```
void NetFEM_Scalar_field(NetFEM n,const double *data,int dataPer,FIELD,const char *name);
subroutine NetFEM_Scalar(n,data,dataPer,FIELD,name)
```

A FIELD version of NetFEM_Scalar.