3D Parallel FEM (III)
Parallel Visualization and ppOpen-HPC

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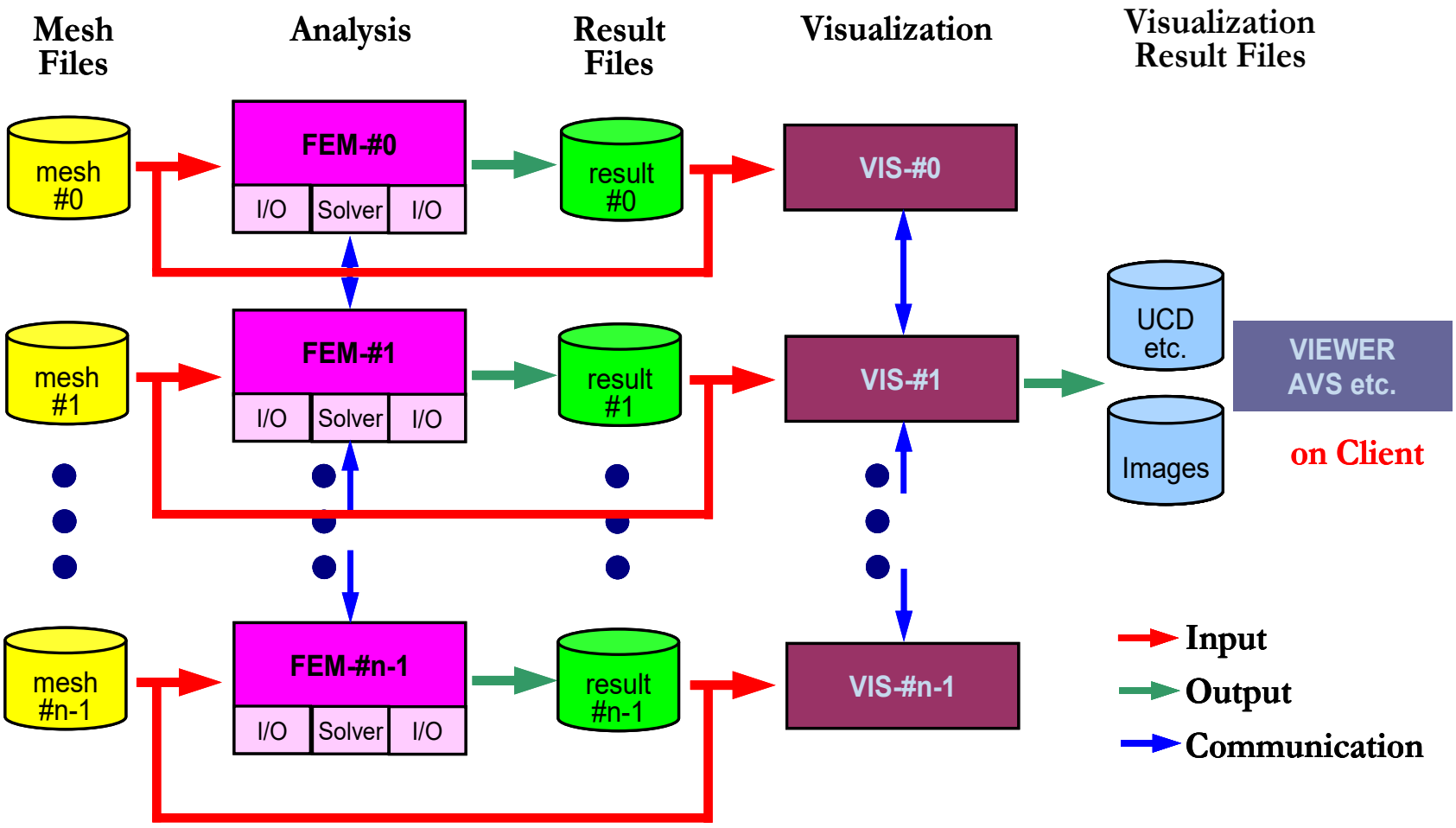
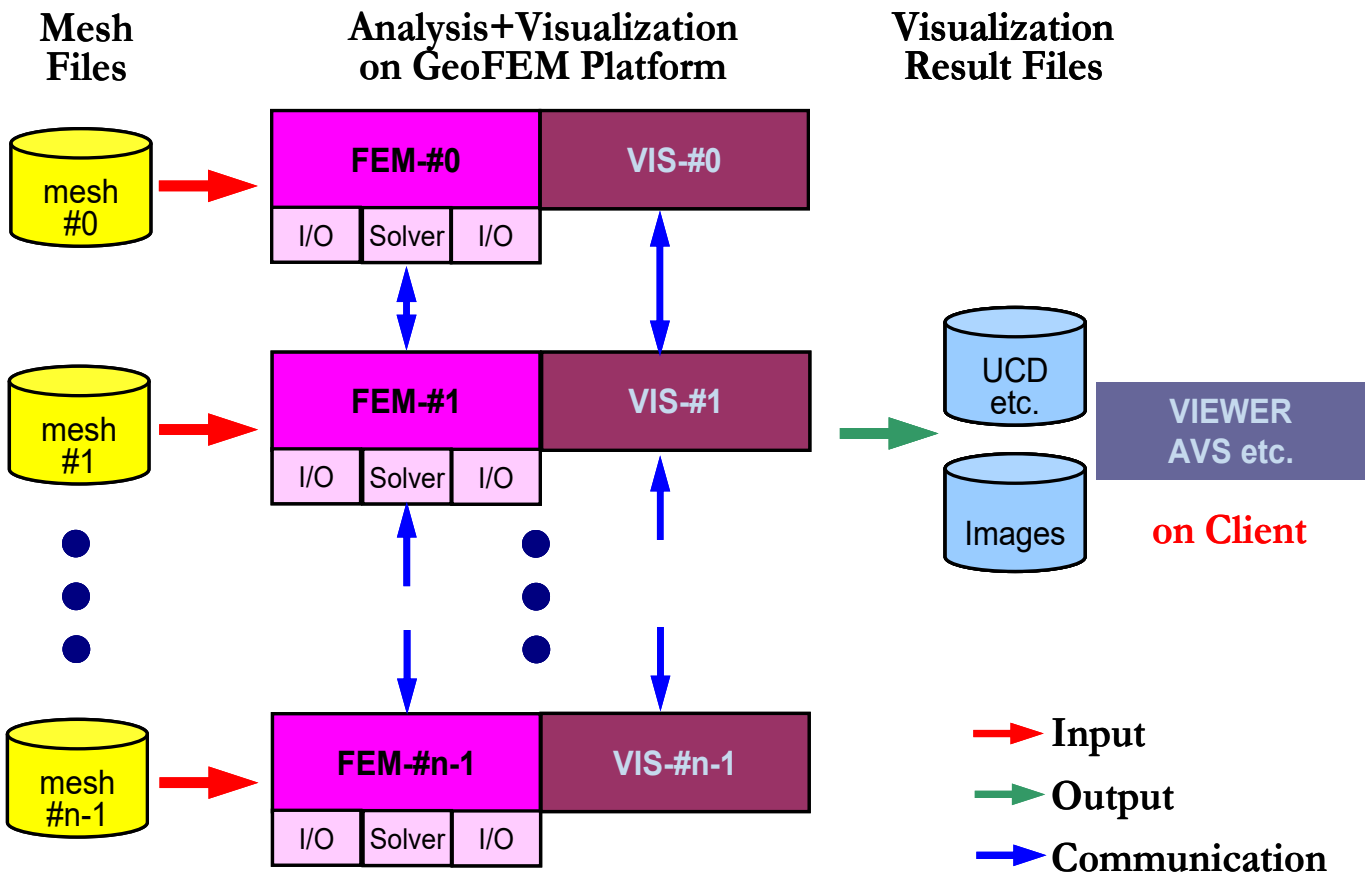
ppOpen-HPC

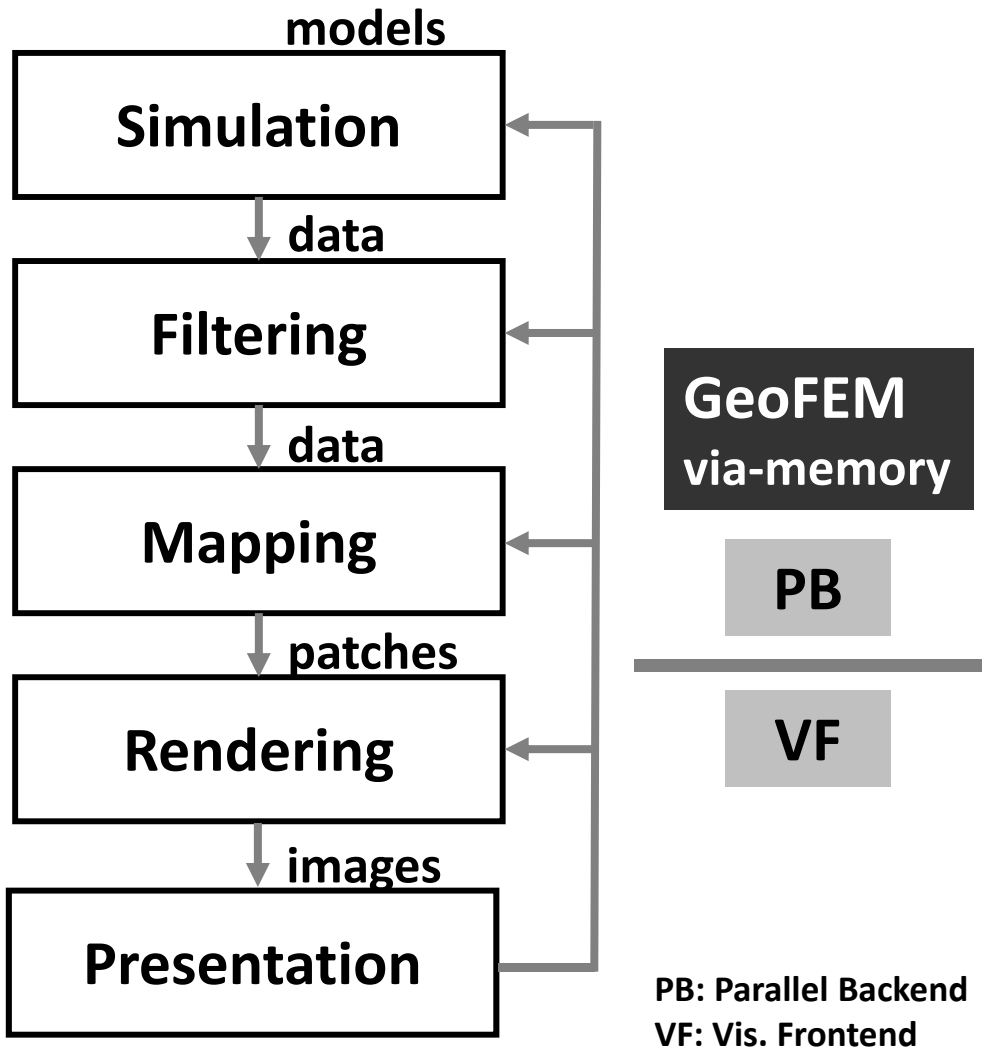
Framework for Parallel Visualization 1 Via-File



Framework for Parallel Visualization 2 Via-Memory (GeoFEM Project)

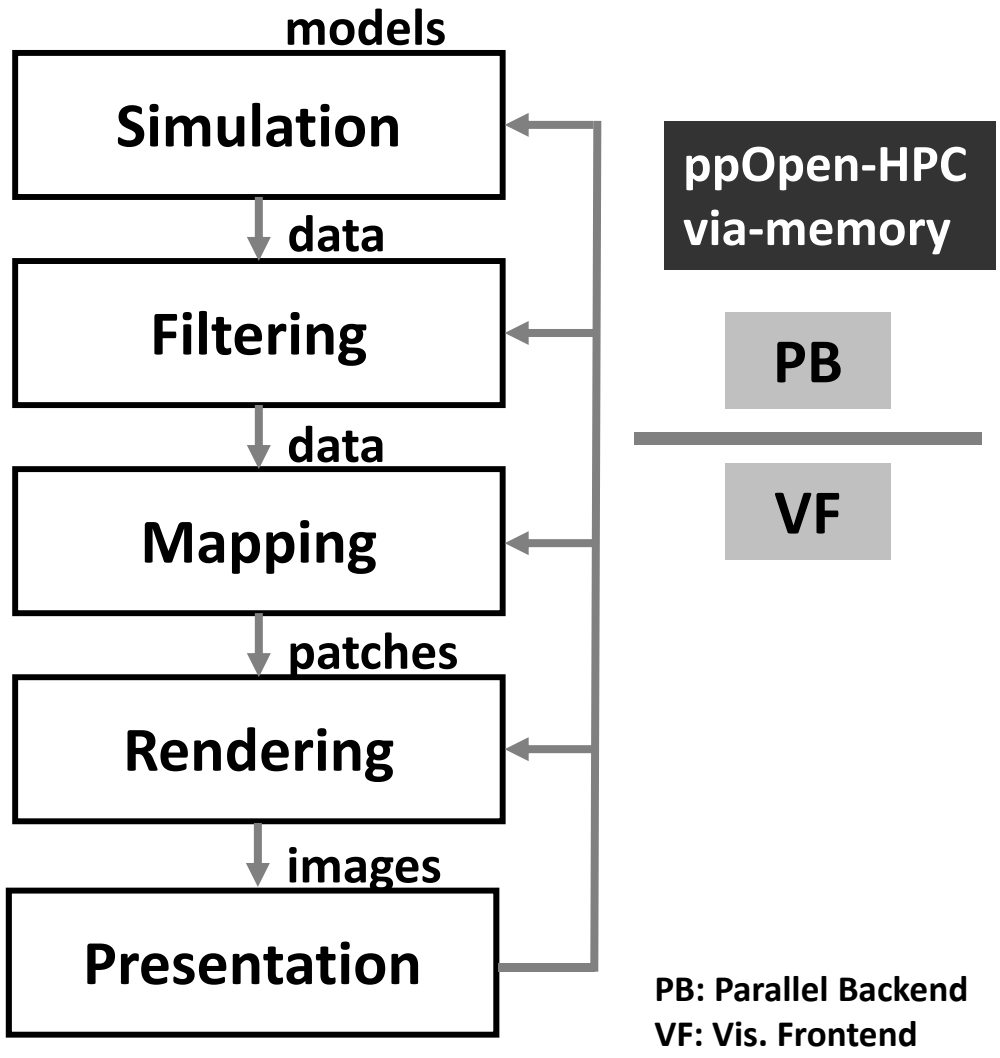


Visualization in ppOpen-HPC



- Concurrent Visualization-Computation
- Output files (single “self-contained（自己完結）” file) are browsed by MicroAVS & Paraview on a PC
- In GeoFEM (previous project), only patch files were obtained.
- Not detailed visualization.
- Just for understanding MIN-MAX, and peaks
- Detailed geometry is preferable

Visualization in ppOpen-HPC



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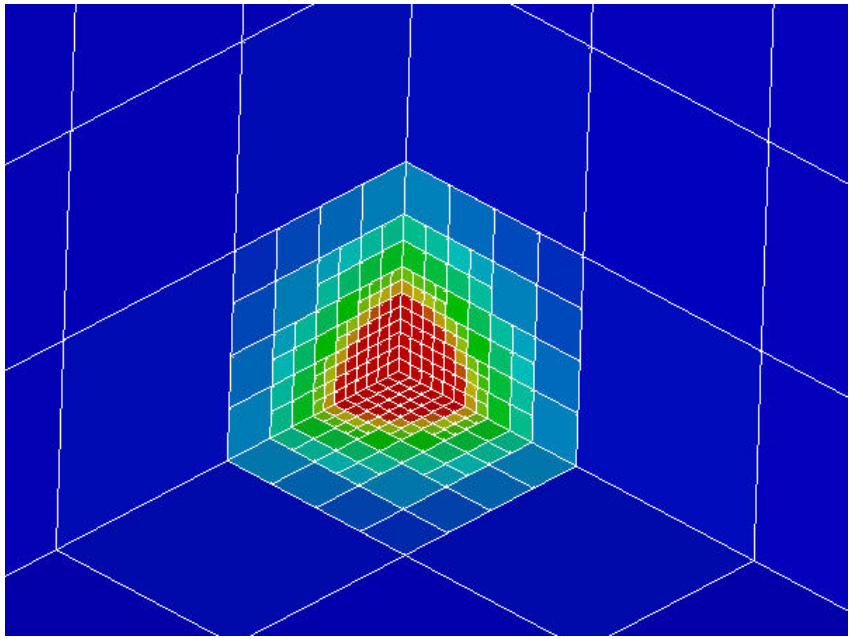
Supercomputer System & Visualization

- Supercomputer is not for “displaying”, but for computing.
- “Re-calculation” for just visualization is not good.
- In supercomputer center, we spend money on computer itself (not for visualization system).

ppOpen-MATH/VIS

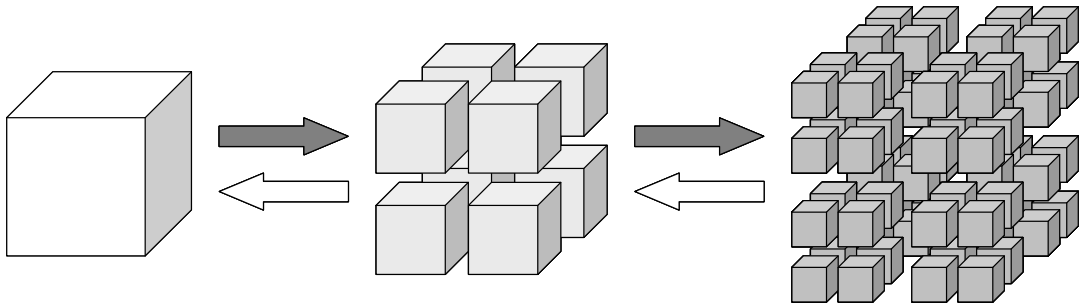
- Parallel Visualization using Information of Background Voxels [Nakajima & Chen 2006]
  - FDM version is released: ppOpen-MATH/VIS-FDM3D
- UCD single file
- Platform
  - T2K, Cray
  - FX10
  - Flat MPI
- Unstructured/Hybrid version
  - Next release

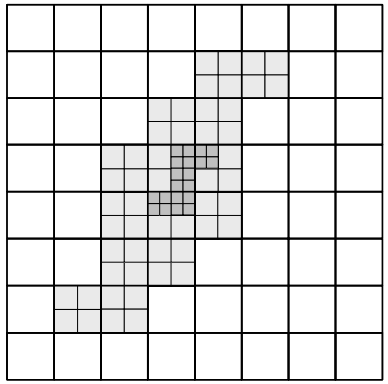


```
[Refine]
AvailableMemory = 2.0    Available memory size (GB), not available in this version.
MaxVoxelCount   = 500    Maximum number of voxels
MaxRefineLevel  = 20     Maximum number of refinement levels
```

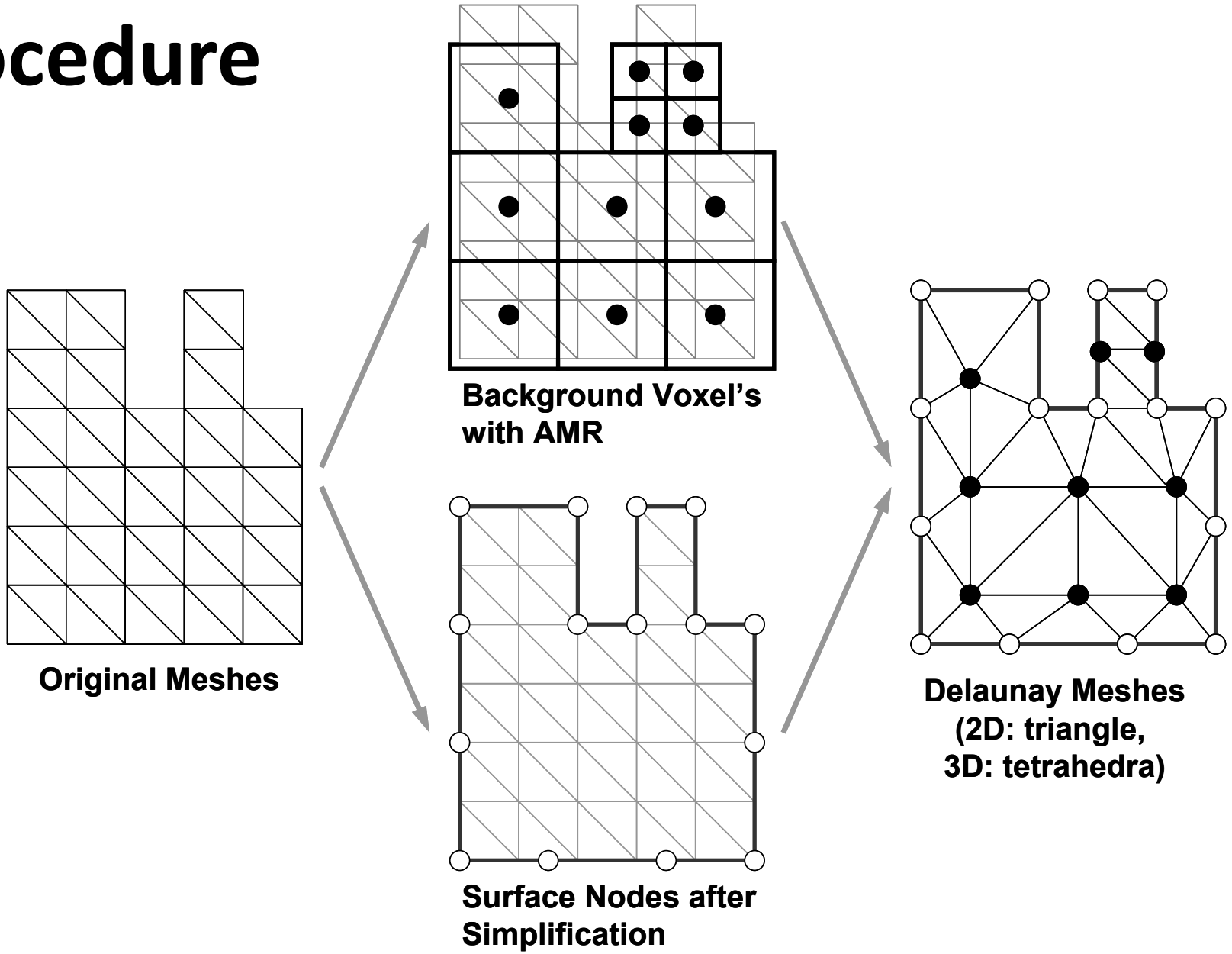
Simplified Parallel Visualization using Background Voxels

- Octree-based AMR
- AMR applied to the region where gradient of field values are large
  - stress concentration, shock wave, separation etc.
- If the number of voxels are controled, a single file with 10^5 meshes is possible, even though entire problem size is 10^9 with distributed data sets.

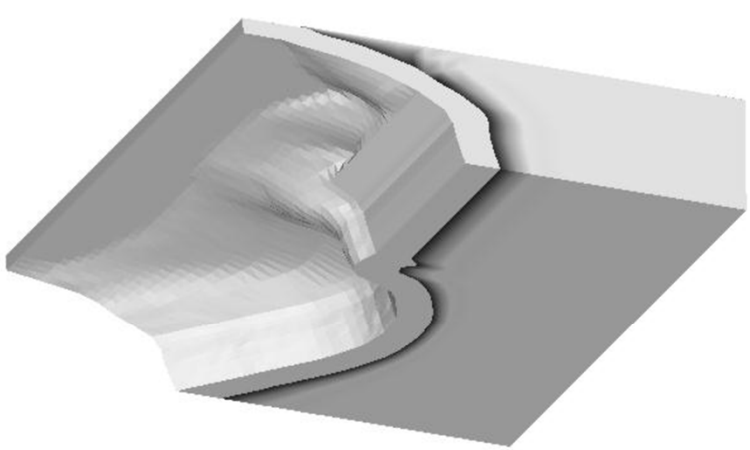


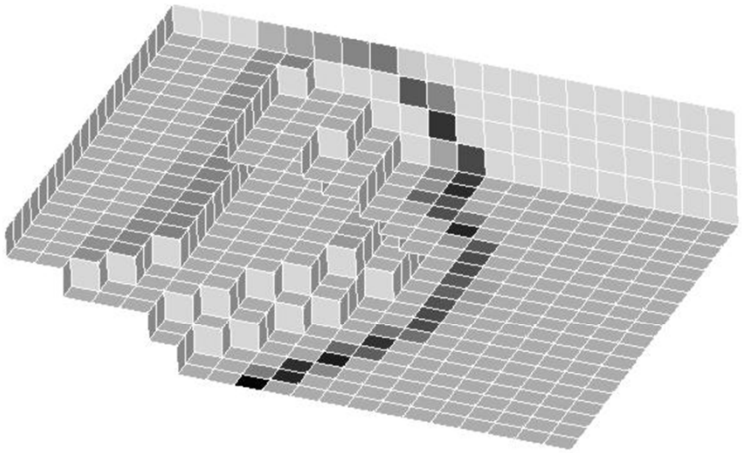


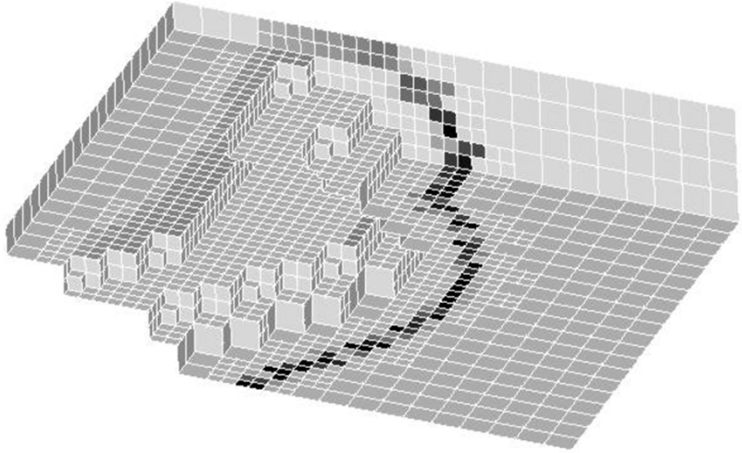
Procedure

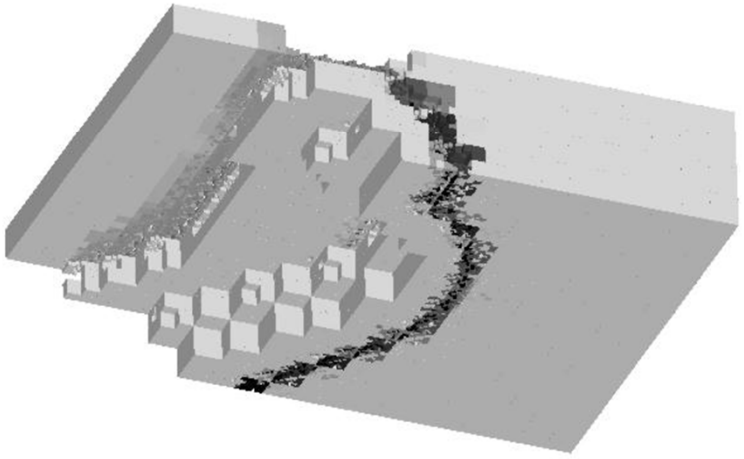

Original Meshes
Background Voxel's with AMR
Surface Nodes after Simplification
Delaunay Meshes (2D: triangle, 3D: tetrahedra)

Voxel Mesh (adapted)

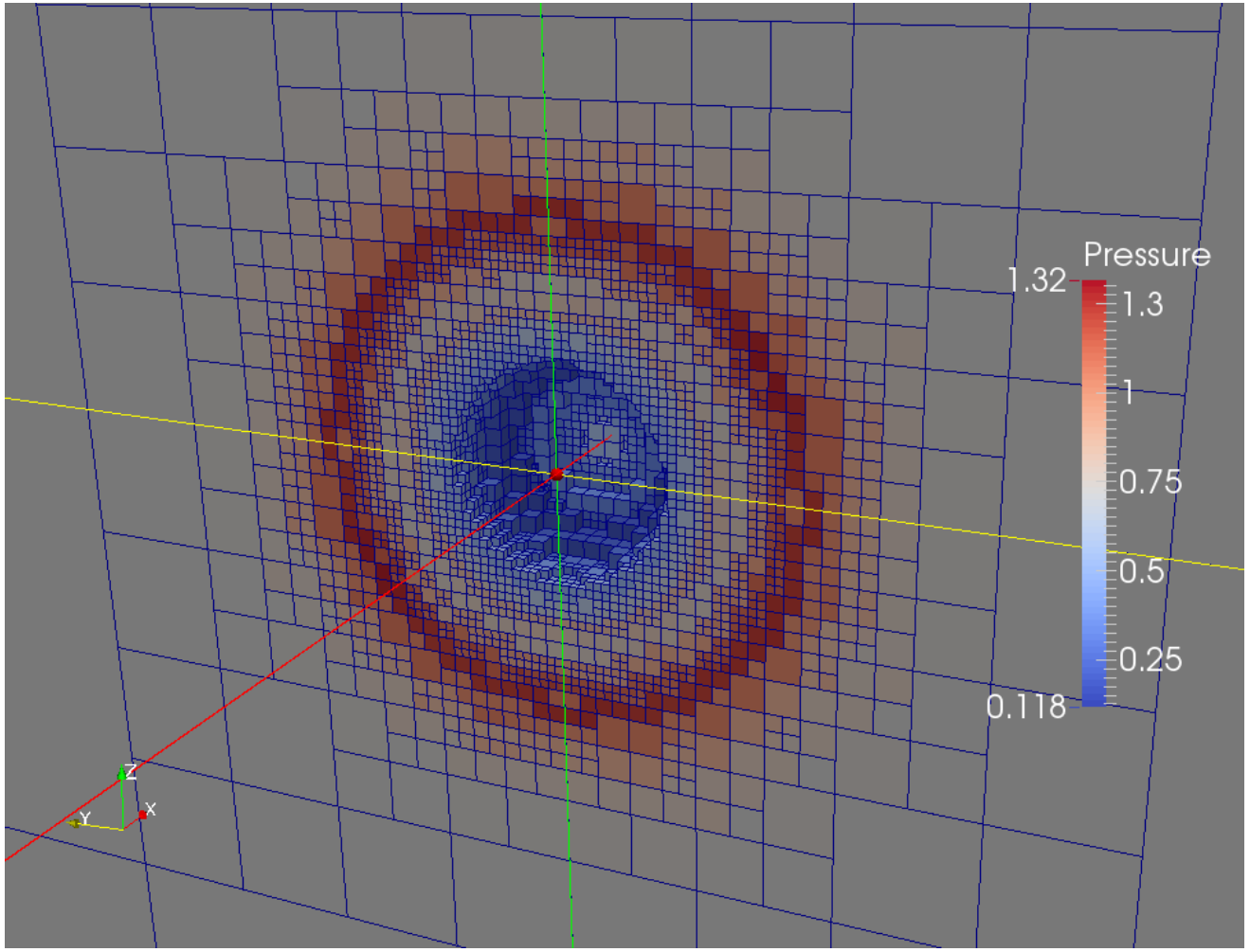








Flow around a sphere



pFEM3D + ppOpen-MATH/VIS

```
>$ cd <$O-TOP>/pfem3d/srcV
>$ make
>$ cd ../run
>$ ls solv
     solv
```

Makefile（Fortran）

```
include Makefile.in

FFLAGSL   = -I/home/z30088/class_eps/include
FLDFLAGSL = -L/home/z30088/class_eps/lib
LIBSL     = -lfppohvispfem3d -lppohvispfem3d

.SUFFIXES:
.SUFFIXES: .o .f90 .f

.f.o:
        $(FC) -c $(FFLAGS) $(FFLAGSL) $< -o $@
.f90.o:
        $(F90) -c $(F90FLAGS) $(FFLAGSL) $< -o $@

TARGET = ../run/solv

OBJS = ¥
        test1.o ...

all: $(TARGET)

$(TARGET): $(OBJS)
        $(F90) -o $(TARGET) $(F90FLAGS) $(FFLAGSL) $(OBJS)
$(LDFLAGSL) $(LIBS) $(LIBSL) $(FLDFLAGSL)
```

Makefile（C）

```
include Makefile.in

CFLAGSL  = -I/home/z30088/class_eps/include
LDFLAGSL = -L/home/z30088/class_eps/lib
LIBSL    = -lppohvispfem3d

.SUFFIXES:
.SUFFIXES: .o .c

.c.o:
        $(CC) -c $(CFLAGS) $(CFLAGSL) $< -o $@

TARGET = ../run/solv

OBJS = ¥
        test1.o ...

all: $(TARGET)

$(TARGET): $(OBJS)
        $(CC) -o $(TARGET) $(CFLAGS) $(CFLAGSL) $(OBJS)
$(LDFLAGSL) $(LIBS) $(LIBSL)
        rm -f *.o *.mod
```

Fortran/main (1/2)

```
      use solver11
      use pfem_util
      use ppohvis_pfem3d_util

      implicit REAL*8(A-H,O-Z)
      type(ppohVIS_BASE_stControl)               :: pControl
      type(ppohVIS_BASE_stResultCollection)      :: pNodeResult
      type(ppohVIS_BASE_stResultCollection)      :: pElemResult
      character(len=PPOHVIS_BASE_FILE_NAME_LEN) :: CtrlName
      character(len=PPOHVIS_BASE_FILE_NAME_LEN) :: VisName
      character(len=PPOHVIS_BASE_LABEL_LEN)      :: ValLabel
      integer(kind=4)                             :: iErr

      CtrlName = ""
      CtrlName = "vis.cnt"

      VisName = ""
      VisName = "vis"

      ValLabel = ""
      ValLabel = "temp"

      call PFEM_INIT

      call ppohVIS_PFEM3D_Init(MPI_COMM_WORLD, iErr)
      call ppohVIS_PFEM3D_GetControl(CtrlName, pControl, iErr);
      call INPUT_CNTL
      call INPUT_GRID

      call ppohVIS_PFEM3D_SETMESHEX(                                    &
     &       NP,      N,           NODE_ID, XYZ,                      &
     &       ICELTOT, ICELTOT_INT, ELEM_ID, ICELNOD,                  &
     &       NEIBPETOT, NEIBPE, IMPORT_INDEX, IMPORT_ITEM,            &
     &                          EXPORT_INDEX, EXPORT_ITEM, iErr)
```

Fortran/main (2/2)

```
      call MAT_ASS_MAIN
      call MAT_ASS_BC

      call SOLVE11

      pNodeResult%ListCount = 1
      pElemResult%ListCount = 0
      allocate(pNodeResult%Results(1))

      call ppohVIS_PFEM3D_ConvResultNodeItem1N(                          &
     &       NP, ValLabel, X, pNodeResult%Results(1), iErr)

      call ppohVIS_PFEM3D_Visualize(pNodeResult, pElemResult, pControl, &
     &                              VisName, 1, iErr)

      call PFEM_FINALIZE

      end program heat3Dp
```

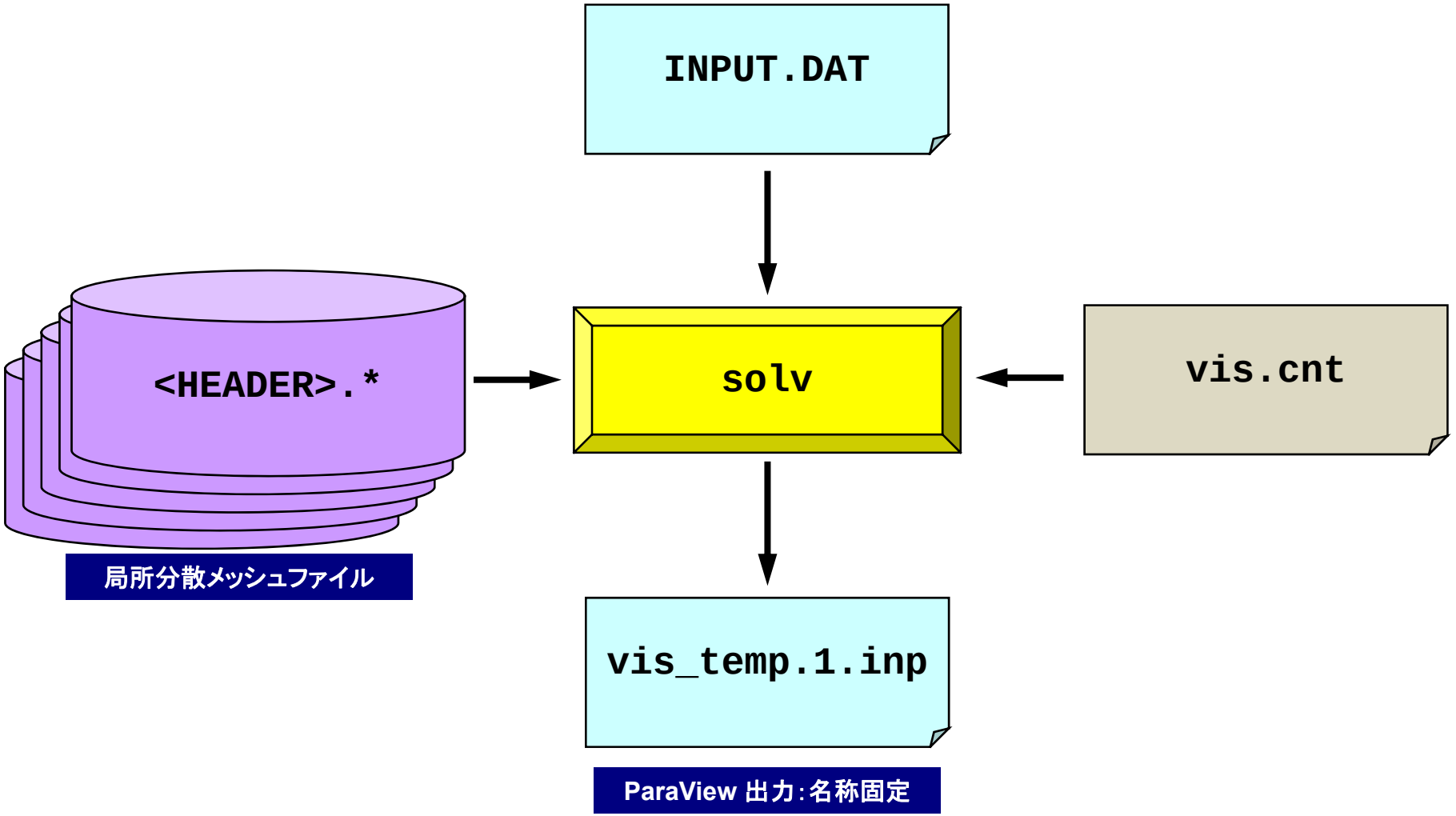
C/main (1/2)

```
#include <stdio.h>
#include <stdlib.h>
FILE* fp_log;
#define GLOBAL_VALUE_DEFINE
#include "pfem_util.h"
#include "ppohVIS_PFEM3D_Util.h"
extern void PFEM_INIT(int,char**);
extern void INPUT_CNTL();
extern void INPUT_GRID();
extern void MAT_CON0();
extern void MAT_CON1();
extern void MAT_ASS_MAIN();
extern void MAT_ASS_BC();
extern void SOLVE11();
extern void OUTPUT_UCD();
extern void PFEM_FINALIZE();
int main(int argc,char* argv[])
{
  double START_TIME,END_TIME;
  struct ppohVIS_FDM3D_stControl *pControl = NULL;
  struct ppohVIS_FDM3D_stResultCollection *pNodeResult = NULL;

  PFEM_INIT(argc,argv);
  ppohVIS_PFEM3D_Init(MPI_COMM_WORLD);
  pControl = ppohVIS_FDM3D_GetControl("vis.cnt");

  INPUT_CNTL();
  INPUT_GRID();

  if(ppohVIS_PFEM3D_SetMeshEx(
      NP,N,NODE_ID,XYZ,
      ICELTOT,ICELTOT_INT,ELEM_ID,ICELNOD,
      NEIBPETOT,NEIBPE,IMPORT_INDEX,IMPORT_ITEM,EXPORT_INDEX,EXPORT_ITEM)) {
                ppohVIS_BASE_PrintError(stderr);
                MPI_Abort(MPI_COMM_WORLD,errno);
  };
```

C/main (2/2)

```
  MAT_CON0();
  MAT_CON1();

  MAT_ASS_MAIN();
  MAT_ASS_BC()  ;

  SOLVE11();

  OUTPUT_UCD();

  pNodeResult=ppohVIS_BASE_AllocateResultCollection();
        if(pNodeResult == NULL) {
                ppohVIS_BASE_PrintError(stderr);
                MPI_Abort(MPI_COMM_WORLD,errno);
        };
        if(ppohVIS_BASE_InitResultCollection(pNodeResult, 1)) {
                ppohVIS_BASE_PrintError(stderr);
                MPI_Abort(MPI_COMM_WORLD,errno);
        };

        pNodeResult->Results[0] =

  ppohVIS_PFEM3D_ConvResultNodeItemPart(NP,1,0,"temp",X);

  START_TIME= MPI_Wtime();
        if(ppohVIS_PFEM3D_Visualize(pNodeResult,NULL,pControl,"vis",1)) {
                ppohVIS_BASE_PrintError(stderr);
                MPI_Abort(MPI_COMM_WORLD,errno);
        };

  ppohVIS_PFEM3D_Finalize();

  PFEM_FINALIZE() ;
}
```

pFEM3D + ppOpen-MATH/VIS



Preparing Distributed Mesh Files

```
>$ cd <$O-TOP>/pfem3d/pmesh
(mesh.inp, mg.sh)

>$ pjsub mg.sh
```

mesh.inp

```
256 256 256
  4   4   4
pcube
```

256^3 nodes into $4 \times 4 \times 4 = 64$ partitions

Each MPI process has 64^3 nodes

mg.sh

```
#!/bin/sh
#PJM -L "node=4"
#PJM -L "elapse=00:05:00"
#PJM -L "rscgrp=lecture1"
#PJM -g “gt91"
#PJM -j
#PJM -o "mg.lst"
#PJM --mpi "proc=64"

mpiexec ./pmesh
rm wk.*
```

Computation + Visualization

```
>$ cd <$O-TOP>/pfem3d/run
(INPUT.DAT, gv.sh)

>$ pjsub gv.sh
```

INPUT.DAT

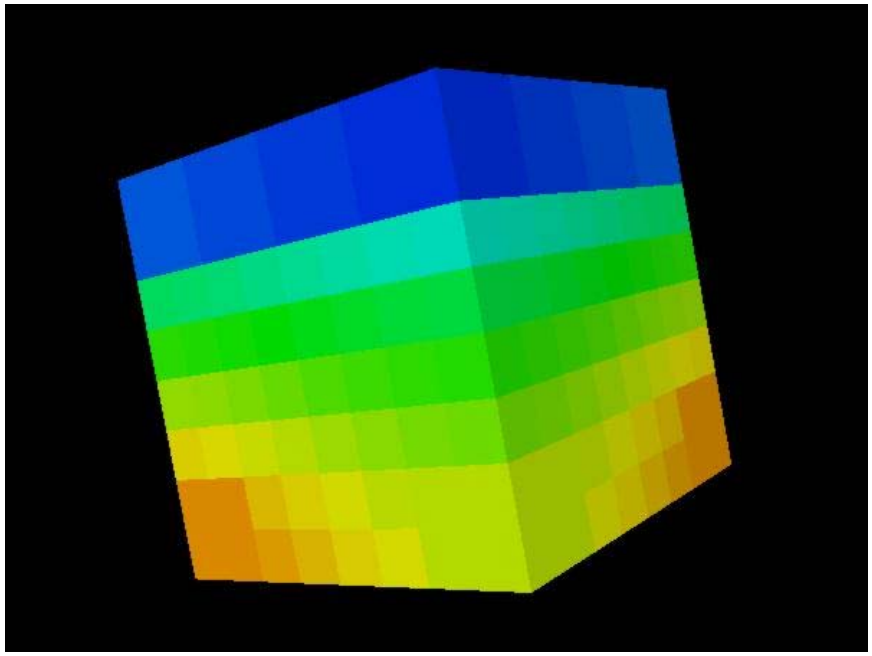
```
../pmesh/pcube
2000
1.0 1.0
1.0e-08
```

gv.sh

```
#!/bin/sh
#PJM -L "node=4"
#PJM -L "elapse=00:10:00"
#PJM -L "rscgrp=lecture1”
#PJM –g “gt91"
#PJM -j
#PJM -o "aa.lst"
#PJM --mpi "proc=64"

mpiexec ./solv
```

vis.cnt

```
[Refine]                    Control Info. for Refinement
AvailableMemory = 2.0       Available Memory (GB) not in use
MaxVoxelCount = 1000        Max Voxel #
MaxRefineLevel = 20         Max Voxel Refinement Level
[Simple]                    Control Info. for Simplification
ReductionRate = 0.0         Reduction Rate of Surface Patches
[Output]                    Output Format
FileFormat    = 2           =1:MicroAVS, =2:ParaView
```



Values at Cell Ctr.

16,777,216 nodes
16,581,375 elem's, 64 MPI proc's

vis_temp.1.inp
1,436 nodes
1,002 elements