Calcul préliminaire : équation de Stokes sur un échantillon du benchmark

TENSYL/Julien

Creation du maillage de l'échantillon

- Un cube (100x100x100) est extrait de l'image 3D
- Pré-traitement en Python avec *Scikit-Image*
- Maillage des surfaces en Python avec *s2m*
- Remplissage (maillage 3D) avec *Gmsh*
- Export

Script FreeFEM++

221110 > benchmark > main.edp

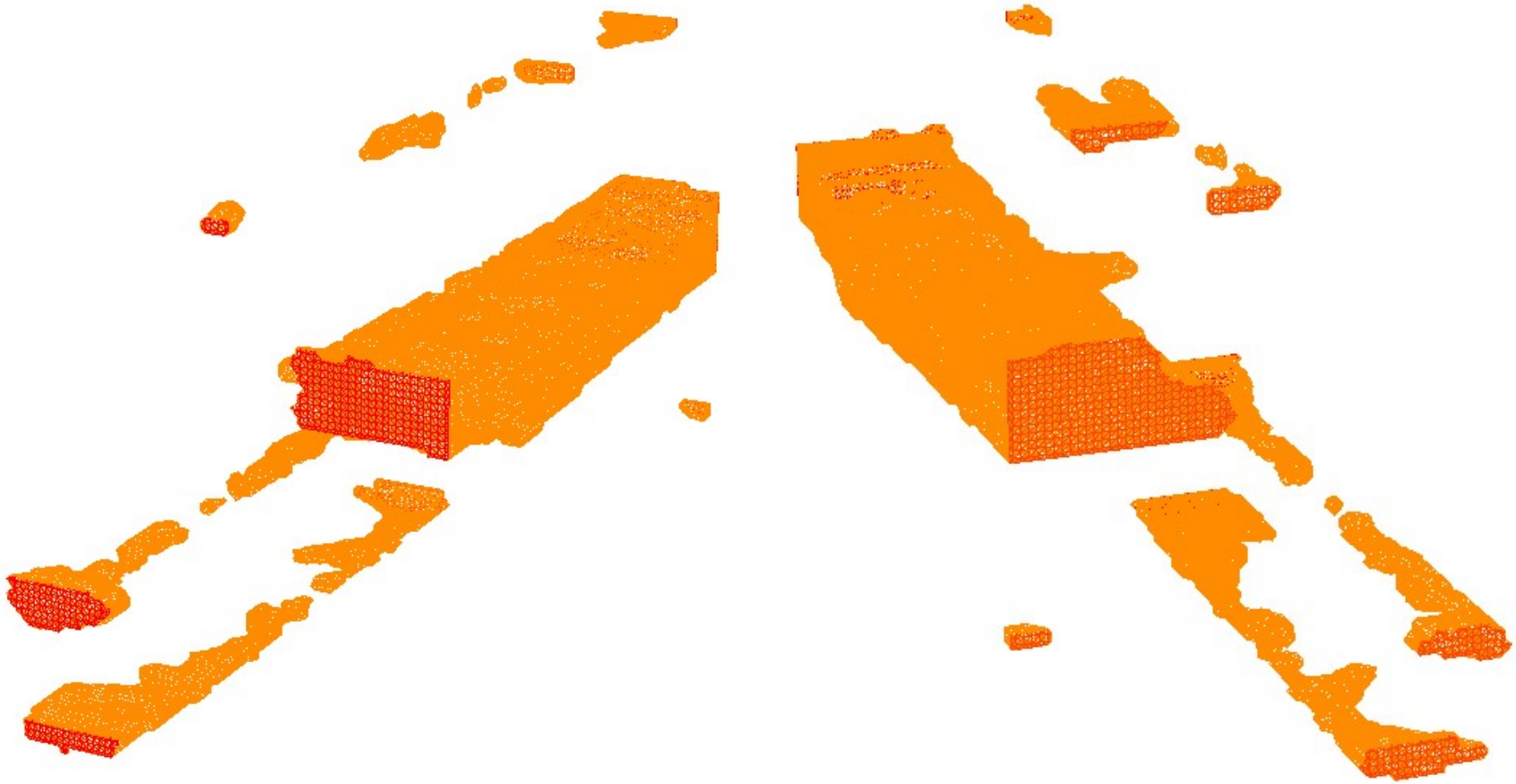
```
load "gmsh"
load "msh3"

mesh3 Th = gmshload3("FormMSH_V2.msh");

real[int] bb(6);    // vecteur des coordonnees min / max par axe
boundingbox(Th, bb);    // ecriture des valeurs dans le vecteur

real eps = (bb[3]-bb[2])*0.1/100;    // tolerance, en pourcentage de la longueur
func newlab = (y < bb[2]+eps) ? 1 : (y > bb[3]-eps ? 2 : 3);    // fonction de modification des labels
Th = change(Th, flabel = newlab);    // application des nouveaux labels sur le probleme

plot(Th, cmm="Th");    // affichage du maillage

fespace VVh(Th,[P23d,P23d,P23d,P13d]) ; // Taylor Hood Finite element.
fespace Vh(Th, P23d);
fespace Wh(Th, P13d);

macro Grad(u) [dx(u),dy(u),dz(u)] // EOM
macro div(u1,u2,u3) (dx(u1)+dy(u2)+dz(u3)) // EOM

varf vStokes([u1,u2,u3,p],[v1,v2,v3,q])
= int3d(Th)(
    Grad(u1)'*Grad(v1) + Grad(u2)'*Grad(v2) + Grad(u3)'*Grad(v3)
    - div(u1,u2,u3)*q - div(v1,v2,v3)*p + 1e-10*q*p )
+ on(3,u1=0,u2=0,u3=0)
+ on(1,u1=1,u2=0,u3=0);

matrix A = vStokes(VVh,VVh);
set(A, solver=UMFPACK);

real[int] b = vStokes(0,VVh);
VVh [u1,u2,u3,p];
u1[] = A^-1 * b;

Vh ux = u1(x,0.5,y);
Vh uz = u3(x,0.5,y);
Wh p2 = p(x,0.5,y);

plot(Th, p2) ;

```

A remplir

Maillage (appel *plot()* ligne 13)

Ordonnées y croissante

Ordonnées y décroissante



Exécution sur l'échantillon 100x100x100

```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>freefem++ main.edp -ns
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_
411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =2328  ( 1304 )

100443 tetrahedrons
36732 triangles
137175 numElements
  Plot::  Sorry no ps version for this type of plot 5
  -- Build Nodes/DF on mesh :   n.v. 26148, n. elmt. 100443, n b. elmt. 36732
     nb of Nodes 171092    nb of DoF   539424  DFon=4300
  -- FESpace: Nb of Nodes 171092 Nb of DoF 539424
  -- Build Nodes/DF on mesh :   n.v. 26148, n. elmt. 100443, n b. elmt. 36732
     nb of Nodes 171092    nb of DoF   171092  DFon=1100
  -- FESpace: Nb of Nodes 171092 Nb of DoF 171092
  -- FESpace: Nb of Nodes 26148 Nb of DoF 26148
 Error Umfpack -1 :  out_of_memory    current line = 34
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>
```

Solutions envisagées

- Changer le nombre de degrés de liberté en modifiant l'espace d'interpolation P23d, revenir à P2.
- Réduire le nombre de volumes élémentaires en coupant le maillage directement depuis FreeFEM++ (ne sélectionner que la partie traversante)
- Réduire le nombre de volumes élémentaires au moment de créer le maillage 3D en manipulant dans Gmsh
- Réduire le nombre de volumes élémentaires au moment de mailler les surfaces en paramétrant le mailleur Python s2m
- Jouer sur la qualité du maillage par un choix *judicieux* des angles min et max entre les faces au moment de créer le maillage avec s2m
- Autoriser le *remeshing* et le *smoothing* au niveau de s2m

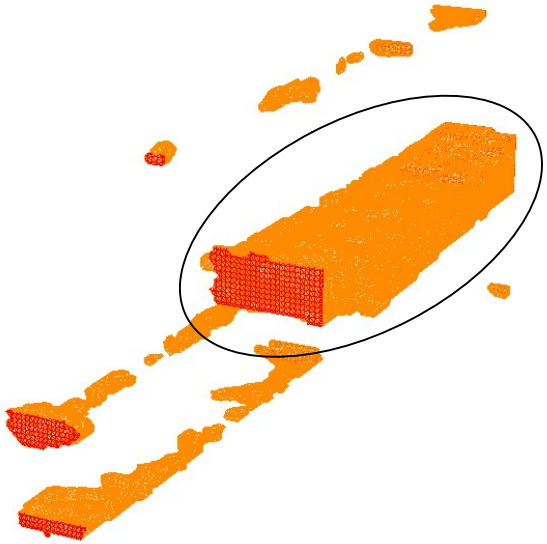
Dégrader l'interpolation : P23d vers P2

```
15    fespace VVh(Th,[P2,P2,P2,P1]) ; // Taylor Hood Finite element.
16    fespace Vh(Th, P2);
17    fespace Wh(Th, P1);
```

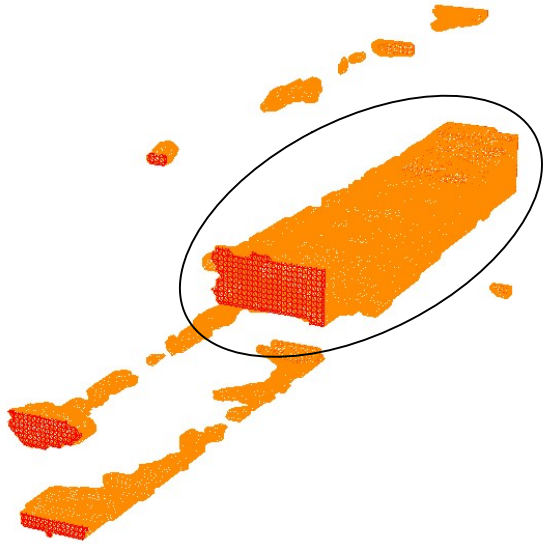
```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>freefem++ main.edp -ns
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_
411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =2328  ( 1304 )

100443 tetrahedrons
36732 triangles
137175 numElements
  Plot::  Sorry no ps version for this type of plot 5
  -- Build Nodes/DF on mesh :   n.v. 26148, n. elmt. 100443, n b. elmt. 36732
     nb of Nodes 171092    nb of DoF   539424  DFon=4300
  -- FESpace: Nb of Nodes 171092 Nb of DoF 539424
  -- Build Nodes/DF on mesh :   n.v. 26148, n. elmt. 100443, n b. elmt. 36732
     nb of Nodes 171092    nb of DoF   171092  DFon=1100
  -- FESpace: Nb of Nodes 171092 Nb of DoF 171092
  -- FESpace: Nb of Nodes 26148 Nb of DoF 26148
 Error Umfpack -1 :  out_of_memory   current line = 34
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>
```

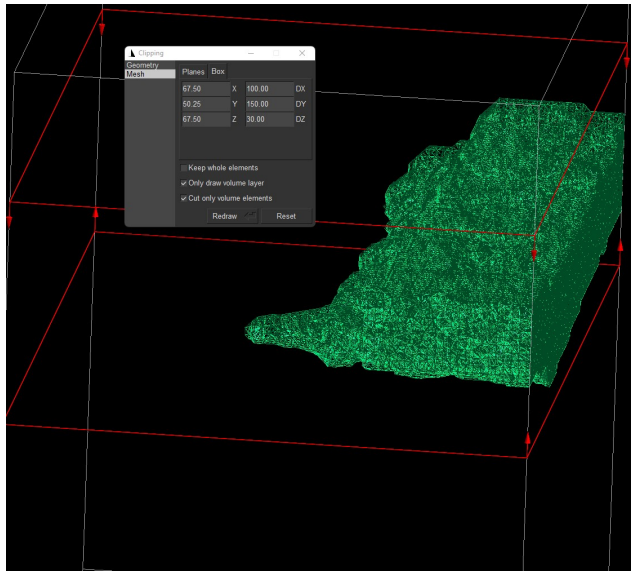
Le nombre de degrés de liberté n'a pas été réduit. Le problème de mémoire persiste.

Tentative de coupe du maillage : ne conserver qu'une composante connexe et traversante depuis FreeFEM++



Tentative de coupe du maillage : ne conserver qu'une composante connexe et traversante depuis Gmsh





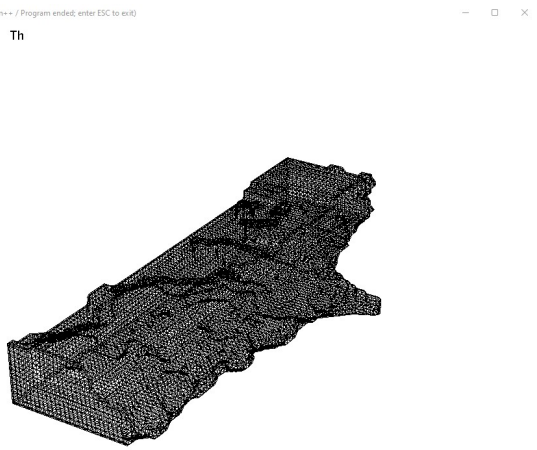
Ouvrir une géométrie (.STL), sélectionner *Mesh* dans le panneau à droite, sélectionner l'outil *Delete* puis appuyer sur <ctrl> pour sélectionner les zones à supprimer. On peut alors exporter le maillage restant.

Alexandre G. a obtenu le maillage clean de cette manière, sur ma machine, Gmsh cesse de fonctionner pendant l'opération.

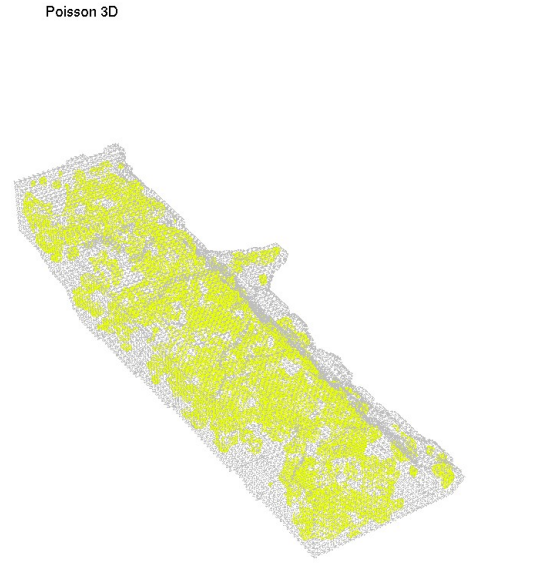
Lecture du maillage coupé et Poisson en 3D

221110 > benchmark > main.edp

```
1   load "gmsh"
2   load "msh3"
3
4   mesh3 Th = gmshload3("gmsh_img_RE_G_100_4_ascii_without_parametric_Clean.msh");
5
6   plot(Th, cmm="Th");    // affichage du maillage
7
8   fespace Vh(Th,P1) ;
9   Vh u, v;
10
11  solve poisson(u, v) = int3d(Th)(dx(u)*dx(v) + dy(u)*dy(v) + dz(u)*dz(v)) + on(0, u=1);
12
13  plot(u, cmm="Poisson 3D") ;
14
```



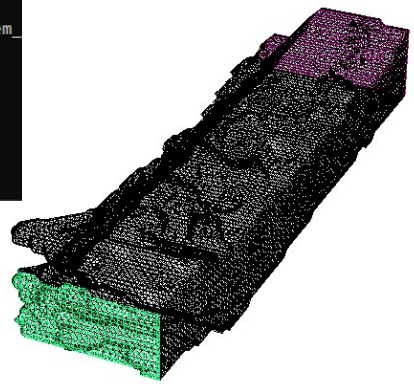

```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>freefem++ main.edp -ns^C
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_
411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =1496  ( 472 )

77340 tetrahedrons
22524 triangles
99864 numElements
  Plot::  Sorry no ps version for this type of plot 5
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
  -- Solve :
          min 1  max 1
  Plot::  Sorry no ps version for this type of plot 6
times: compile 0.031s, execution 1.67s,  mpirank:0
 ######## We forget of deleting   45 Nb pointer,   0Bytes  ,  mpirank 0, memory leak =0
 CodeAlloc : nb ptr  3823,  size :516080 mpirank: 0
Ok: Normal End

C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>
```



Mise en place de labels pour le calcul de Stokes en 3D

Th

```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>freefem++ main.edp -ns
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_
411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =1308  ( 284 )

 77340 tetrahedrons
 22524 triangles
 99864 numElements
  Plot::  Sorry no ps version for this type of plot 5
times: compile 0.016s, execution 0.889s,  mpirank:0
```



221110 > benchmark > main.edp

```
1   load "gmsh"
2   load "msh3"
3
4   mesh3 Th = gmshload3("gmsh_img_RE_G_100_4_ascii_without_parametric_Clean.msh");    // lecture du maillage coupe
5
6   real[int] bb(6);    // vecteur de six nombres reels
7   boundingbox(Th, bb);    // remplissage du vecteur bb avec les valeurs min / max de chaque coordonnee du maillage
8   real eps = (bb[3]-bb[2])*0.1/100;    // tolerance numerique sur la position (axe ey), en pourcentage de la longueur
9
10  int inflow = 10;     // label du bord d'entree
11  int outflow = 20;    // label du bord de sortie
12  int noslip = 30;     // label du bord impermeable
13
14  func newlab = (y < bb[2]+eps) ? inflow : (y > bb[3]-eps ? outflow : noslip);    // fonction numerique d'affectation des labels
15
16  Th = change(Th, flabel=newlab);    // "flabel" plutot que "label" car appel d'une fonction
17
18  plot(Th, cmm="Th");    // affichage du maillage
19
```

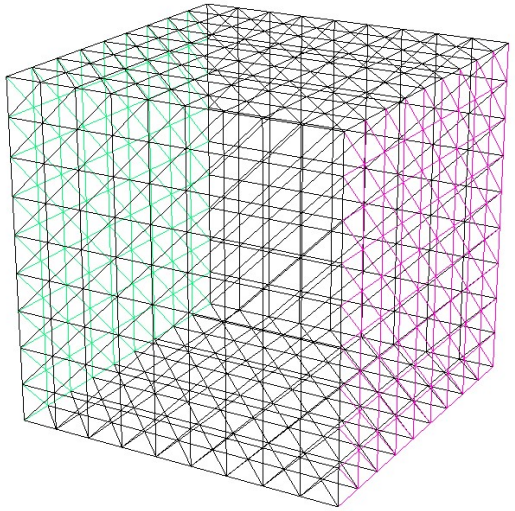
A remplir

Équation de Stokes en 3D sur le cube unité

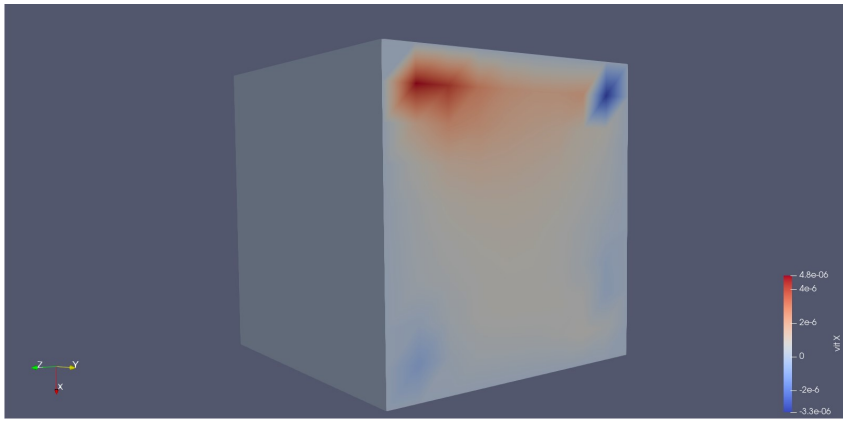
221110 > benchmark > stokes3D.edp

```
load "iovtk"
load "msh3"
int[int] ordre = [1];

int inflow = 10;
int outflow = 20;
int noslip = 30;
int[int] labs = [inflow, noslip, outflow, noslip, noslip, noslip];

int nel = 9;

mesh3 Th = cube(nel, nel, nel, label=labs);

plot(Th);

fespace Vh(Th, [P2, P2, P2]);
fespace Ph(Th, P1);
Vh [ux, uy, uz], [vx, vy, vz];
Ph p, q;

macro grad(w) [dx(w), dy(w), dz(w)] //EOM
macro div(wx, wy, wz) (dx(wx) + dy(wy) + dz(wz)) //EOM

solve stokes([ux, uy, uz, p], [vx, vy, vz, q])
= int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz] + 1e-10*p*q)
+ on(noslip, ux=0, uy=0, uz=0)
+ on(inflow, p=1)
+ on(outflow, p=0)
;

plot([ux, uy, uz], p, cmm="Poiseuille", value=1);
savevtk("vit.vtu", Th, [ux, uy, uz], dataname="vit", order=ordre);

```

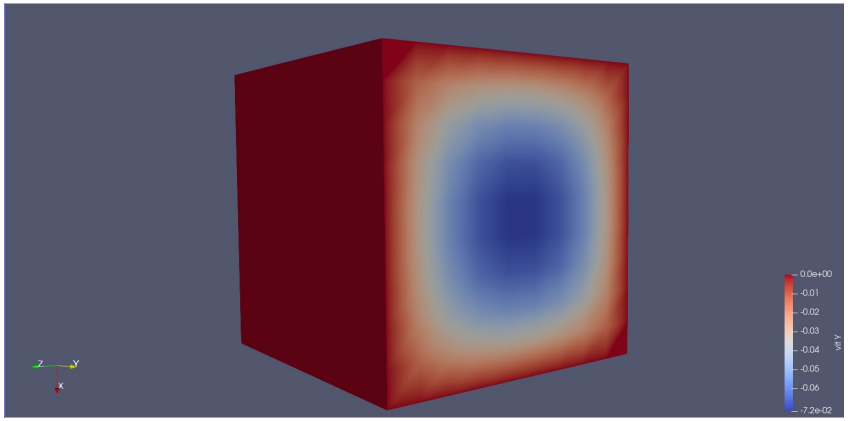
Résultats (écoulement de Poiseuille 3D)



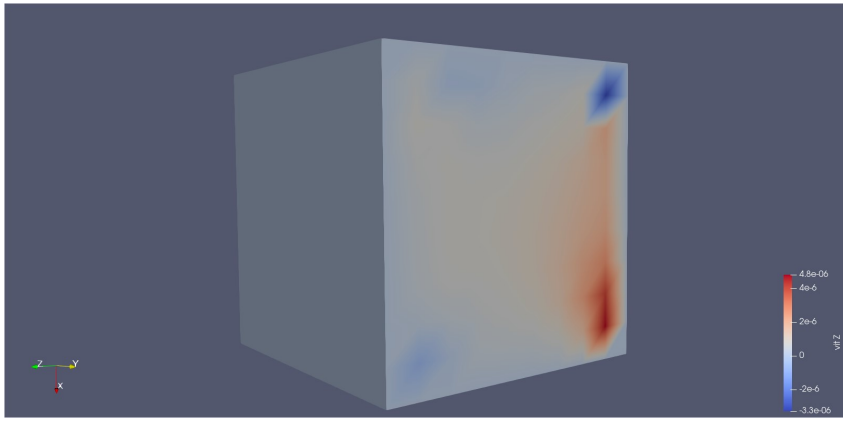
vx



vy



vz



Stokes – Poiseuille sur le maillage 3.D du benchmark

221110 > benchmark > main.edp

```
load "gmsh"
load "iovtk"
load "msh3"
int[int] ordre = [1];

mesh3 Th = gmshload3("gmsh_img_RE_G_100_4_ascii_without_parametric_Clean.msh");    // lecture du maillage coupe

real[int] bb(6);    // vecteur de six nombres reels
boundingbox(Th, bb);    // remplissage du vecteur bb avec les valeurs min / max de chaque coordonnee du maillage
real eps = (bb[3]-bb[2])*0.1/100;    // tolerance numerique sur la position (axe ey), en pourcentage de la longueur

int inflow = 10;     // label du bord d'entree
int outflow = 20;    // label du bord de sortie
int noslip = 30;     // label du bord impermeable

func newlab = (y < bb[2]+eps) ? inflow : (y > bb[3]-eps ? outflow : noslip);    // fonction numerique d'affectation des labels

Th = change(Th, flabel=newlab);    // "flabel" plutot que "label" car appel d'une fonction

// plot(Th, cmm="Th");    // affichage du maillage

fespace Vh(Th, [P2, P2, P2]);
fespace Ph(Th, P1);
Vh [ux, uy, uz], [vx, vy, vz];
Ph p, q;

macro grad(w) [dx(w), dy(w), dz(w)] //EOM
macro div(wx, wy, wz) (dx(wx) + dy(wy) + dz(wz)) //EOM

solve stokes([ux, uy, uz, p], [vx, vy, vz, q])
= int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz] + 1e-10*p*q)
+ on(noslip, ux=0, uy=0, uz=0)
+ on(inflow, p=1)
+ on(outflow, p=0)
;

plot([ux, uy, uz], p, cmm="Poiseuille", value=1);
savevtk("vit.vtu", Th, [ux, uy, uz], dataname="vit", order=ordre);

```

Résultat

```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>^Cfreefem++ main.edp -ns
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_
411\FreeFem++\\.\iovtk = 0) load: iovtk
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =1840  ( 816 )

77340 tetrahedrons
22524 triangles
99864 numElements
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   375825  DFon=3300
  -- FESpace: Nb of Nodes 125275 Nb of DoF 375825
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   394162  DFon=4300
 Error Umfpack -1 :  out_of_memory    current line = 34
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 catch an erreur in  solve  =>  set  sol = 0 !!!!!!!
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>
```

Exécution d'un code d'Alexandre pour comparer les problèmes de mémoire

```
C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>freefem++ 221107_LectureMaillage3D_main_REF.edp -ns
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : 221107_LectureMaillage3D_main_REF.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\medit = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_411\Fre
eFem++\\.\msh3 = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programm
es\Freefem_411\FreeFem++\\.\iovtk = 0) load: iovtk
 sizestack + 1024 =2168  ( 1144 )

77340 tetrahedrons
22524 triangles
99864 numElements
  Plot::  Sorry no ps version for this type of plot 5
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
Nombre de Tetrahedre =77340
boundingbox:
xmin = 59, xmax = 100, ymin = 0, ymax = 100, zmin = 56, zmax = 75
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   375825  DFon=3300
  -- FESpace: Nb of Nodes 125275 Nb of DoF 375825
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   394162  DFon=4300
 Error Umfpack -1 :  out_of_memory   current line = 93
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 catch an erreur in  solve  =>  set  sol = 0 !!!!!!!
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark>
```

Plus de verbosité pour le solver par défaut (1/2)

```
C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>freefem++ main.edp -ns -v 10
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main.edp  verbosity= 10
 Load:  callInitsFunct : 2

 addInitFunct : -10000 call : 1 (  )
 addInitFunct : -20 call : 1 ( lg_fem  OneFFSlverVS 47 47
 OneFFSlverVS 47 47
 OneFFSlverVS 63 63
 OneFFSlverVS 63 63
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
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 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 49 49
 OneFFSlverVS 49 49
 OneFFSlverVS 58 58
 OneFFSlverVS 58 58
 ) lg_mesh  glumesh2D lg_mesh3 eigenvalue
 ****  gmsh.cpp ****
 -- addInitFunct: 10000 1 gmsh.cpp
 test LoadLibrary(C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh) = 0x7ffe7eb60000
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0) callInitsFunct : 1

 addInitFunct : 10000 call : 1 (
 loadfile gmsh.cpp
 load: gmsh
 )  ****  iovtk.cpp ****
 -- addInitFunct: 10000 1 iovtk.cpp
 test LoadLibrary(C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\iovtk) = 0x7ffe7e790000
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\iovtk = 0) callInitsFunct : 1

 addInitFunct : 10000 call : 1 (
 loadfile iovtk.cpp
 load: iovtk
 )  ****  msh3.cpp ****
 -- addInitFunct: 10000 1 msh3.cpp
 test LoadLibrary(C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3) = 0x7ffe63860000
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3 = 0) callInitsFunct : 1

 addInitFunct : 10000 call : 1 (
 loadfile msh3.cpp
 load: msh3
 ) Load mesh given by GMSH
 on : ux n 0 = ?
 on : uy n 1 = ?
```

```
 ) Load mesh given by GMSH
 on : ux n 0 = ?
 on : uy n 1 = ?
 on : uz n 2 = ?
  on 0 0x16078c940e0
  on 1 0x16078c94320
  on 2 0x16078c94340
 on : p n 3 = ?
  on 3 0x16078c942e0
 on : p n 3 = ?
  on 3 0x16078c943c0

 new expression : 576 mi=1 9EConstantIdE : ((d) 1)

 new expression : 656 mi=1 9EConstantIdE : ((d) -1)

 new expression : 736 mi=1 9EConstantIdE : ((d) 1e-10)
  -- Problem type  ( complex : 0 )
Write Mesh and Solutions in VTK Formats
 sizestack + 1024 =1840  ( 816 )

18337 vertices
closing file 77340 22524
77340 tetrahedrons
22524 triangles
99864 numElements
  -- GMesh3 , n V: 18337 , n Elm: 77340 , n B Elm: 22524mes 29824.7 9148.37 , bb: (59 0 56) , (100 100 75)
   -- BuildAdj:nva= 3 4 22524
  -- BuildAdj:0x16028464fd0 nb Elememt 77340 nb vertices 18337
            : nb adj  = 165942 on border 22524 nea = 4 nva = 3 nb no manifold border 0

    ~HashTable:   Cas moyen : 3.57159
 number of real boundary element 22524
  GTree: box: 59 0 56 100 100 75 38.5 -50 46.5 120.5 150 84.5 nbv : 18337
MaxISize 1073741824
  -- End of read: mesure = 29824.7 border mesure 9148.37
      timers Mesh3 :0.003 0.031 0.002 0 0.003
  -- GMesh3 , n V: 18337 , n Elm: 77340 , n B Elm: 22524mes 29824.7 9148.37 , bb: (59 0 56) , (100 100 75)
   -- BuildAdj:nva= 3 4 22524
  -- BuildAdj:0x16028466350 nb Elememt 77340 nb vertices 18337
            : nb adj  = 165942 on border 22524 nea = 4 nva = 3 nb no manifold border 0

    ~HashTable:   Cas moyen : 3.57159
 number of real boundary element 22524
  GTree: box: 59 0 56 100 100 75 38.5 -50 46.5 120.5 150 84.5 nbv : 18337
MaxISize 1073741824
  -- End of read: mesure = 29824.7 border mesure 9148.37
      timers Mesh3 :0.002 0.034 0.004 0.001 0.006
destroy mesh30x16028464fd0 destroy meshS 0
OpMake_pfes_np :: 0 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 1 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 2 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
 NbDoF : 30
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
10 nb equi be :  0
     -- BuildDF: iteration in final equivalent 1 nb change 0
    ~HashTable:   Cas moyen : 0
    ~HashTable:   Cas moyen : 4.49869
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   375825  DFon=3300
  -- FESpace: Nb of Nodes 125275 Nb of DoF 375825
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
  **Warning: set default solver to UMFPACK
 NbDoF : 34
```

Plus de verbosité pour le solver par défaut (2/2)

```
  **Warning: set default solver to UMFPACK
 NbDoF : 34
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
      comp 3 [30, 34[
10 nb equi be :  0
     -- BuildDF: iteration in final equivalent 1 nb change 0
    ~HashTable:   Cas moyen : 0
    ~HashTable:   Cas moyen : 4.49869
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 125275    nb of DoF   394162  DFon=4300
   -- Change of Mesh 0  0x16028466350
   Problem(): initmat 1 VF (discontinuous Galerkin) = 0
   -- size of Matrix 0 Bytes
  -- discontinuous Galerkin  =0 size of Mat =0 Bytes
  --  int3d   (nQP: 14 ) in  Optimized = 1,  all
 ** Search solver UMFPACK sym = 0 pos.  0 half 0
 ** Find solver UMFPACK ts: 49 sym = 0 pos.  0 half 0
 build solver UMFPACK double/int
 ## SetSolver 0x160284a0dd0 0 0x16078d5f0e0
 UpdateState 1 1
 VirtualSolver :: factorize state:0 st= 3
fac_symbolic UMFPACK R: nnz U  nnz= 34895926
 CheckUmfpackStatus 0
fac_numeric UMFPACK R: nnz U  nnz= 34895926
 CheckUmfpackStatus -1
 Error Umfpack -1 :  out_of_memory    current line = 34
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 catch an erreur in  solve  =>  set  sol = 0 !!!!!!!
    ~HashMatrix:   Mean collision in hash: 1.7234 0x160284a0dd0 rank: 0 matmul 0s
destroy mesh30x16028466350 destroy meshS 0
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>
```

Comparaison avec Stokes sur un cube (1/2)

```
C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>freefem++ C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark\stokes3D.edp -ns -v 10
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : C:\Users\jvalentin\Desktop\WORKSPACE\221110\benchmark\stokes3D.edp  verbosity= 10
 Load:  callInitsFunct : 2

 addInitFunct : -10000 call : 1 (  )
 addInitFunct : -20 call : 1 ( lg_fem  OneFFSlverVS 47 47
 OneFFSlverVS 47 47
 OneFFSlverVS 63 63
 OneFFSlverVS 63 63
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 49 49
 OneFFSlverVS 49 49
 OneFFSlverVS 58 58
 OneFFSlverVS 58 58
 OneFFSlverVS 47 47
 OneFFSlverVS 47 47
 OneFFSlverVS 63 63
 OneFFSlverVS 63 63
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 31 31
 OneFFSlverVS 49 49
 OneFFSlverVS 49 49
 OneFFSlverVS 58 58
 OneFFSlverVS 58 58
 ) lg_mesh  glumesh2D lg_mesh3 eigenvalue
 ****  iovtk.cpp ****
 -- addInitFunct: 10000 1 iovtk.cpp
 test LoadLibrary(C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\iovtk) = 0x7ffe8ad90000
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\iovtk = 0) callInitsFunct : 1

 addInitFunct : 10000 call : 1 (
 loadfile iovtk.cpp
 load: iovtk
 )  ****  msh3.cpp ****
 -- addInitFunct: 10000 1 msh3.cpp
 test LoadLibrary(C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3) = 0x7ffe89f00000
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3 = 0) callInitsFunct : 1

 addInitFunct : 10000 call : 1 (
 loadfile msh3.cpp
 load: msh3
 )  on : ux n 0 = ?
 on : uy n 1 = ?
 on : uz n 2 = ?
  on 0 0x2807a27e190
  on 1 0x2807a27da90
  on 2 0x2807a27daf0
 on : p n 3 = ?
  on 3 0x2807a27db50
 on : p n 3 = ?
  on 3 0x2807a27dc10

 new expression : 576 mi=1 9EConstantIdE : ((d) 1)

 new expression : 656 mi=1 9EConstantIdE : ((d) -1)
```

```
 new expression : 656 mi=1 9EConstantIdE : ((d) -1)

 new expression : 736 mi=1 9EConstantIdE : ((d) 1e-10)
  -- Problem type  ( complex : 0 )
Write Mesh and Solutions in VTK Formats
 sizestack + 1024 =1840  ( 816 )

  Enter: BuildCube: 6
   Cube:  kind = 6 n tet Cube = 6 / n slip 6 70
  -- Cube  nv=1000 nt=4374 nbe=972 kind= 6
  Out:  BuildCube
  -- GMesh3 , n V: 1000 , n Elm: 4374 , n B Elm: 972mes 1 6 , bb: (0 0 0) , (1 1 1)
   -- BuildAdj:nva= 3 4 972
  -- BuildAdj:0x2807a2367a0 nb Elememt 4374 nb vertices 1000
            : nb adj  = 9234 on border 972 nea = 4 nva = 3 nb no manifold border 0

    ~HashTable:   Cas moyen : 3.0222
 number of real boundary element 972
  GTree: box: 0 0 0 1 1 1 -0.5 -0.5 -0.5 1.5 1.5 1.5 nbv : 1000
MaxISize 1073741824
  -- End of read: mesure = 1 border mesure 6
      timers Mesh3 :0.003 0.011 0 0 0.003
 cube timers 0.001 0.011   Mesh3  0.017
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 5
OpMake_pfes_np :: 0 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 1 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 2 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
 NbDoF : 30
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
10 nb equi be :  0
     -- BuildDF: iteration in final equivalent 1 nb change 0
    ~HashTable:   Cas moyen : 0
    ~HashTable:   Cas moyen : 3.34609
  -- Build Nodes/DF on mesh :   n.v. 1000, n. elmt. 4374, n b. elmt. 972
     nb of Nodes 6859    nb of DoF   20577  DFon=3300
  -- FESpace: Nb of Nodes 6859 Nb of DoF 20577
  -- FESpace: Nb of Nodes 1000 Nb of DoF 1000
  **Warning: set default solver to UMFPACK
 NbDoF : 34
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
      comp 3 [30, 34[
10 nb equi be :  0
     -- BuildDF: iteration in final equivalent 1 nb change 0
    ~HashTable:   Cas moyen : 0
    ~HashTable:   Cas moyen : 3.34609
  -- Build Nodes/DF on mesh :   n.v. 1000, n. elmt. 4374, n b. elmt. 972
     nb of Nodes 6859    nb of DoF   21577  DFon=4300
   -- Change of Mesh 0  0x2807a2367a0
   Problem(): initmat 1 VF (discontinuous Galerkin) = 0
   -- size of Matrix 0 Bytes
  -- discontinuous Galerkin  =0 size of Mat =0 Bytes
  --  int3d   (nQP: 14 ) in  Optimized = 1,  all
 ** Search solver UMFPACK sym = 0 pos.  0 half 0
 ** Find solver UMFPACK ts: 49 sym = 0 pos.  0 half 0
 build solver UMFPACK double/int
 ## SetSolver 0x2807ab8cd70 0 0x2807b070080
 UpdateState 1 1
 VirtualSolver :: factorize state:0 st= 3
```

A remplir

Comparaison avec Stokes sur un cube (2/2)

```
 ## SetSolver 0x2807ab8cd70 0 0x2807b070080
 UpdateState 1 1
 VirtualSolver :: factorize state:0 st= 3
fac_symbolic UMFPACK R: nnz U  nnz= 1937131
 CheckUmfpackStatus 0
fac_numeric UMFPACK R: nnz U  nnz= 1937131
 CheckUmfpackStatus 0
dosolver UMFPACK double/int  1 0
 CheckUmfpackStatus 0
UMFPACK V5.7.9 (Oct 20, 2019), Info:
    matrix entry defined as:          double
    Int (generic integer) defined as: int
    BLAS library used: Fortran BLAS.  size of BLAS integer: 4
    MATLAB:                           no.
    CPU timer:                        none.
    number of rows in matrix A:       21577
    number of columns in matrix A:    21577
    entries in matrix A:              1937131
    memory usage reported in:         8-byte Units
    size of int:                      4 bytes
    size of SuiteSparse_long:         8 bytes
    size of pointer:                  8 bytes
    size of numerical entry:          8 bytes

    strategy used:                    symmetric
    ordering used:                    amd on A+A'
    modify Q during factorization:    no
    prefer diagonal pivoting:         yes
    pivots with zero Markowitz cost:              0
    submatrix S after removing zero-cost pivots:
        number of "dense" rows:                   0
        number of "dense" columns:                0
        number of empty rows:                     0
        number of empty columns                   0
        submatrix S square and diagonal preserved
    pattern of square submatrix S:
        number rows and columns                   21577
        symmetry of nonzero pattern:              1.000000
        nz in S+S' (excl. diagonal):              1915554
        nz on diagonal of matrix S:               21577
        fraction of nz on diagonal:               1.000000
    AMD statistics, for strict diagonal pivoting:
        est. flops for LU factorization:          4.65548e+10
        est. nz in L+U (incl. diagonal):          31269421
        est. largest front (# entries):           8334769
        est. max nz in any column of L:           2887
        number of "dense" rows/columns in S+S':   0
    symbolic factorization defragmentations:      0
    symbolic memory usage (Units):                3565692
    symbolic memory usage (MBytes):               27.2
    Symbolic size (Units):                        56793
    Symbolic size (MBytes):                       0
    symbolic factorization wallclock time(sec):   0.00

    matrix scaled: yes (divided each row by sum of abs values in each row)
    minimum sum (abs (rows of A)):            2.28395e-02
    maximum sum (abs (rows of A)):            1.00000e+30

    symbolic/numeric factorization:      upper bound              actual      %
    variable-sized part of Numeric object:
        initial size (Units)                 5158102             5114944    99%
        peak size (Units)                  236527398            48908694    21%
        final size (Units)                 201683765            30692826    15%
    Numeric final size (Units)             201824060            30822333    15%
    Numeric final size (MBytes)              1539.8              235.2    15%
    peak memory usage (Units)              236865672            49246968    21%
```

```
    symbolic/numeric factorization:      upper bound              actual      %
    variable-sized part of Numeric object:
        initial size (Units)                 5158102             5114944    99%
        peak size (Units)                  236527398            48908694    21%
        final size (Units)                 201683765            30692826    15%
    Numeric final size (Units)             201824060            30822333    15%
    Numeric final size (MBytes)              1539.8              235.2    15%
    peak memory usage (Units)              236865672            49246968    21%
    peak memory usage (MBytes)               1807.1              375.7    21%
    numeric factorization flops          8.93324e+11         4.63364e+10     5%
    nz in L (incl diagonal)                 69694199            15222041    22%
    nz in U (incl diagonal)                125204674            15221365    12%
    nz in L+U (incl diagonal)              194877296            30421829    16%
    largest front (# entries)               39763961             8334769    21%
    largest # rows in front                     4831                2887    60%
    largest # columns in front                  8971                2887    32%

    initial allocation ratio used:                0.204
    # of forced updates due to frontal growth:    0
    number of off-diagonal pivots:                3
    nz in L (incl diagonal), if none dropped      15222041
    nz in U (incl diagonal), if none dropped      15221365
    number of small entries dropped               0
    nonzeros on diagonal of U:                    21577
    min abs. value on diagonal of U:              3.82e-05
    max abs. value on diagonal of U:              1.00e+00
    estimate of reciprocal of condition number:   3.82e-05
    indices in compressed pattern:                577681
    numerical values stored in Numeric object:    30421831
    numeric factorization defragmentations:       1
    numeric factorization reallocations:          1
    costly numeric factorization reallocations:   1
    numeric factorization wallclock time (sec):   0.00

    solve flops:                                  2.10190e+08
    iterative refinement steps taken:             1
    iterative refinement steps attempted:         2
    sparse backward error omega1:                 3.50e-16
    sparse backward error omega2:                 1.33e-48
    solve wall clock time (sec):                  0.00

    total symbolic + numeric + solve flops:       4.65466e+10

  -- Solve :
         min -0.0736693  max 6.38874e-06
         min -8.78e-34  max 1
 Send plot:what: 7 0 43740 6.38874e-06 -9.66737e-06
 Send plot:what: 6 0 17496 1 -8.78e-34
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 7
  Plot::  Sorry no ps version for this type of plot 6
   iovtk writeMesh3: names  "vit"
   iovtk writeMesh3:value of iii=0 vit
    ~HashMatrix:   Mean collision in hash: 1.50204 0x2807ab8cd70 rank: 0 matmul 0s
destroy mesh30x2807a2367a0 destroy meshS 0
times: compile 1.099s, execution 3.749s,  mpirank:0
 ######## We forget of deleting   8838 Nb pointer,   0Bytes  ,  mpirank 0, memory leak =0
 CodeAlloc : nb ptr  3984,  size :526784 mpirank: 0
Ok: Normal End

C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>
```

A remplir

Analyse des sorties avec verbosité 10

Stokes sur le cube

- Le statut du solver est 0 tout le long de la vérification et du travail du solver par défaut

Stokes sur le maillage *clean*

- Le statut du solver est -1 (erreur de capacité de mémoire) dès le deuxième check (fin de la capture d'écran slide 18)

Reprise du problème de Stokes sur le cube pour 13 et 14 éléments par axe

TENSYL

```
   matrix scaled: yes (divided each row by sum of abs values in each row)
   minimum sum (abs (rows of A)):             1.09467e-02
   maximum sum (abs (rows of A)):             1.00000e+30

   symbolic/numeric factorization:      upper bound               actual      %
   variable-sized part of Numeric object:
       initial size (Units)               15184714            15061125    99%
       peak size (Units)                1320612583           197072686    15%
       final size (Units)               1146428933           152363401    13%
   Numeric final size (Units)           1146830632           152734204    13%
   Numeric final size (MBytes)             8749.6               1165.3    13%
   peak memory usage (Units)            1321559609           198019712    15%
   peak memory usage (MBytes)             10082.7               1510.8    15%
   numeric factorization flops         1.09770e+13          4.67464e+11     4%
   nz in L (incl diagonal)               413403861            75765191    18%
   nz in U (incl diagonal)               696947850            75764483    11%
   nz in L+U (incl diagonal)            1110289918           151467881    14%
   largest front (# entries)             185685111            36036009    19%
   largest # rows in front                   11911                6003    50%
   largest # columns in front                17991                6003    33%

   initial allocation ratio used:                0.173
   # of forced updates due to frontal growth:    0
   number of off-diagonal pivots:                3
   nz in L (incl diagonal), if none dropped      75765191
   nz in U (incl diagonal), if none dropped      75764483
   number of small entries dropped               0
   nonzeros on diagonal of U:                    61793
   min abs. value on diagonal of U:              2.65e-05
   max abs. value on diagonal of U:              1.00e+00
   estimate of reciprocal of condition number:   2.65e-05
   indices in compressed pattern:                1896950
   numerical values stored in Numeric object:    151467888
   numeric factorization defragmentations:       1
   numeric factorization reallocations:          1
   costly numeric factorization reallocations:   1
   numeric factorization wallclock time (sec):   0.00

   solve flops:                                  9.90333e+08
   iterative refinement steps taken:             1
   iterative refinement steps attempted:         2
   sparse backward error omega1:                 4.09e-16
   sparse backward error omega2:                 3.70e-25
   solve wall clock time (sec):                  0.00

   total symbolic + numeric + solve flops:       4.68454e+11

  -- Solve :
         min -0.0736709  max 3.05843e-06
         min -4.28656e-34  max 1
 Send plot:what: 7 0 131820 3.05843e-06 -4.63705e-06
 Send plot:what: 6 0 52728 1 -4.28656e-34
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 7
  Plot::  Sorry no ps version for this type of plot 6
   iovtk writeMesh3: names  "vit"
   iovtk writeMesh3:value of iii=0 vit
    ~HashMatrix:   Mean collision in hash: 1.53764 0x2c5c79164f0 rank: 0 matmul 0s
destroy mesh30x2c5c78d7f10 destroy meshS 0
times: compile 0.124s, execution 16.434s,  mpirank:0
 ######## We forget of deleting   26453 Nb pointer,   0Bytes  ,  mpirank 0, memory leak =0
 CodeAlloc : nb ptr  3984,  size :526784 mpirank: 0
```

N éléments = 13 (par axe) ; Nb of DoF : 61 793

```
  -- BuildAdj:0x1afbd4265d0 nb Elememt 16464 nb vertices 3375
           : nb adj  = 34104 on border 2352 nea = 4 nva = 3 nb no manifold border 0

   ~HashTable:   Cas moyen : 3.16866
 number of real boundary element 2352
  GTree: box: 0 0 0 1 1 1 -0.5 -0.5 -0.5 1.5 1.5 1.5 nbv : 3375
MaxISize 1073741824
  -- End of read: mesure = 1 border mesure 6
     timers Mesh3 :0.002 0.011 0.001 0 0.001
 cube timers 0.001 0.002   Mesh3  0.018
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 5
OpMake_pfes_np :: 0 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 1 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
OpMake_pfes_np :: 2 0 2333 N5Fem2D9GTypeOfFEINS_5Mesh3EEE
 NbDoF : 30
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
10 nb equi be :  0
    -- BuildDF: iteration in final equivalent 1 nb change 0
   ~HashTable:   Cas moyen : 0
   ~HashTable:   Cas moyen : 3.3892
  -- Build Nodes/DF on mesh :   n.v. 3375, n. elmt. 16464, n b. elmt. 2352
     nb of Nodes 24389    nb of DoF   73167  DFon=3300
  -- FESpace: Nb of Nodes 24389 Nb of DoF 73167
  -- FESpace: Nb of Nodes 3375 Nb of DoF 3375
  **Warning: set default solver to UMFPACK
 NbDoF : 34
      comp 0 [0, 10[
      comp 1 [10, 20[
      comp 2 [20, 30[
      comp 3 [30, 34[
10 nb equi be :  0
    -- BuildDF: iteration in final equivalent 1 nb change 0
   ~HashTable:   Cas moyen : 0
   ~HashTable:   Cas moyen : 3.3892
  -- Build Nodes/DF on mesh :   n.v. 3375, n. elmt. 16464, n b. elmt. 2352
     nb of Nodes 24389    nb of DoF   76542  DFon=4300
   -- Change of Mesh 0  0x1afbd4265d0
   Problem(): initmat 1 VF (discontinuous Galerkin) = 0
   -- size of Matrix 0 Bytes
  -- discontinuous Galerkin  =0 size of Mat =0 Bytes
  --  int3d   (nQP: 14 ) in  Optimized = 1,  all
 ** Search solver UMFPACK sym = 0 pos.  0 half 0
 ** Find solver UMFPACK ts: 49 sym = 0 pos.  0 half 0
 build solver UMFPACK double/int
 ## SetSolver 0x1affdd83c90 0 0x1affe1ed2c0
 UpdateState 1 1
 VirtualSolver :: factorize state:0 st= 3
fac_symbolic UMFPACK R: nnz U  nnz= 7110406
 CheckUmfpackStatus 0
fac_numeric UMFPACK R: nnz U  nnz= 7110406
 CheckUmfpackStatus -1
 Error Umfpack -1 :  out_of_memory   current line = 28
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 catch an erreur in  solve  =>  set  sol = 0 !!!!!!!
    ~HashMatrix:   Mean collision in hash: 1.49998 0x1affdd83c90 rank: 0 matmul 0s
destroy mesh30x1afbd4265d0 destroy meshS 0
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
```

N éléments = 14 (par axe)

A remplir

Implémentation en *varf*… ?

221114 > benchmark > stokes3D_varf.edp

```
load "iovtk"
load "msh3"
int[int] ordre = [1];

int inflow = 10;
int outflow = 20;
int noslip = 30;
int[int] labs = [inflow, noslip, outflow, noslip, noslip, noslip];

int nel = 14;

mesh3 Th = cube(nel, nel, nel, label=labs);

plot(Th);

fespace Vh(Th, [P2, P2, P2, P1]);
Vh [ux, uy, uz, p];

macro grad(w) [dx(w), dy(w), dz(w)] //EOM
macro div(wx, wy, wz) (dx(wx) + dy(wy) + dz(wz)) //EOM

varf stokes([ux, uy, uz, p], [vx, vy, vz, q])
= int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz] + 1e-10*p*q)
+ on(noslip, ux=0, uy=0, uz=0)
+ on(inflow, p=1)
+ on(outflow, p=0)
;

matrix A = stokes(Vh, Vh);
real[int] b = stokes(0, Vh);

ux[] = A^(-1)*b;

plot([ux, uy, uz], p, cmm="Poiseuille", value=1);
savevtk("vit.vtu", Th, [ux, uy, uz], dataname="vit", order=ordre);
```

```
 VirtualSolver :: factorize state:0 st= 3
fac_symbolic UMFPACK R: nnz U  nnz= 7110406
 CheckUmfpackStatus 0
fac_numeric UMFPACK R: nnz U  nnz= 7110406
 CheckUmfpackStatus -1
 Error Umfpack -1 :  out_of_memory   current line = 32
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 ## SetSolver 0x1d8f9ef1940 0x1d8fa15c010 0
    ~HashMatrix:   Mean collision in hash: 1.50685 0x1d8f9ef1940 rank: 0 matmul 0s
destroy mesh30x1d8a1555aa0 destroy meshS 0
Exec error :  Error Umfpack -1 :  out_of_memory
   -- number :1
 err code 8 ,  mpirank 0

C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>
```

A remplir

Essais sur différents solvers

- Les solvers sont des algorithmes, deux solvers différents peuvent donc exiger des quantités de mémoire différentes. L'erreur est obtenue avec le solver UMPACK, cependant plusieurs autres sont implémentés :
  - LU
  - Cholesky
  - Crout
  - MUMPs…
- LU : convient pour tout système carré
- Cholesky : convient pour tout système symétrique défini positif
- Crout : convient pour tout système carré
- GMRES : algorithme itératif

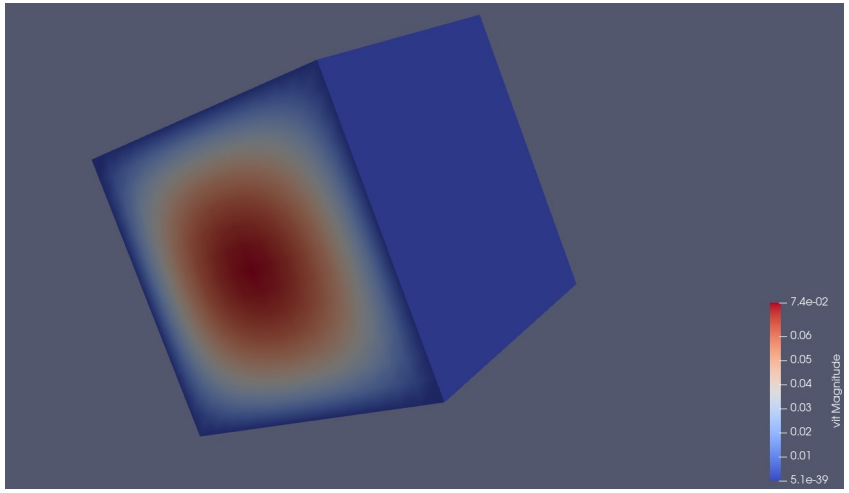
- /!\ La factorisation d'une matrice creuse n'a aucune raison d'être elle-même creuse ! /!\ C'est une piste pour comprendre les problèmes de mémoire. On préfère donc les algorithmes itératifs dans ce cas.

Résolution de Stokes sur le cube pour 14 éléments

221114 > benchmark > stokes3D_varf.edp

```
load "iovtk"
load "msh3"
int[int] ordre = [1];

int inflow = 10;
int outflow = 20;
int noslip = 30;
int[int] labs = [inflow, noslip, outflow, noslip, noslip, noslip];

int nel = 21;

mesh3 Th = cube(nel, nel, nel, label=labs);

plot(Th);

fespace Vh(Th, [P2, P2, P2, P1]);
Vh [ux, uy, uz, p];

macro grad(w) [dx(w), dy(w), dz(w)] //EOM
macro div(wx, wy, wz) (dx(wx) + dy(wy) + dz(wz)) //EOM

varf stokes([ux, uy, uz, p], [vx, vy, vz, q])
= int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz])
+ on(noslip, ux=0, uy=0, uz=0)
+ on(inflow, p=1)
+ on(outflow, p=0)
;

matrix A = stokes(Vh, Vh);
set(A, solver="gmres");
real[int] b = stokes(0, Vh);

ux[] = A^(-1)*b;

plot([ux, uy, uz], p, cmm="Poiseuille", value=1);
savevtk("vit.vtu", Th, [ux, uy, uz], dataname="vit", order=ordre);
```

```
    fgmres has converged in 1028 iterations The relative residual is 9.95414e-07
 cpu CGMatVirt 0 s / 0 nb mul
 cpu CGMatVirt 12.515 s / 1031 nb mul
 Send plot:what: 7 0 164640 0.00013351 -0.000132117
 Send plot:what: 6 0 164640 1 -3.73714e-34
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 7
  Plot::  Sorry no ps version for this type of plot 6
   iovtk writeMesh3: names  "vit"
   iovtk writeMesh3:value of iii=0 vit
 ## SetSolver 0x2dc4fab7800 0x2dc4f9d4d90 0
 cpu CGMatVirt 0.231 s / 2058 nb mul
    ~HashMatrix:   Mean collision in hash: 1.51121 0x2dc4fab7800 rank: 0 matmul 12.515s
destroy mesh30x2dc4fa75610 destroy meshS 0
times: compile 0.047s, execution 74.308s,  mpirank:0
 ######## We forget of deleting   81 Nb pointer,   0Bytes   ,  mpirank 0, memory leak =0
 CodeAlloc : nb ptr  3982,  size :526912 mpirank: 0
Ok: Normal End

C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>
```



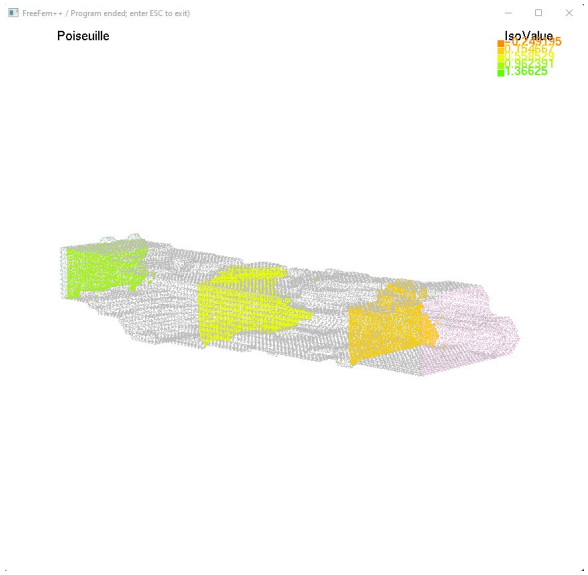
A remplir

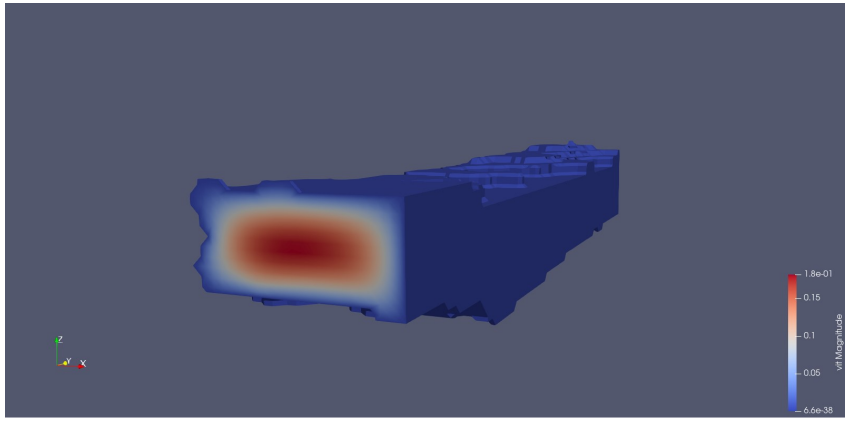
Résolution de Stokes sur le maillage *clean* avec le solver GMRES

Execution ~ 2h

~ 0.5 s / iter

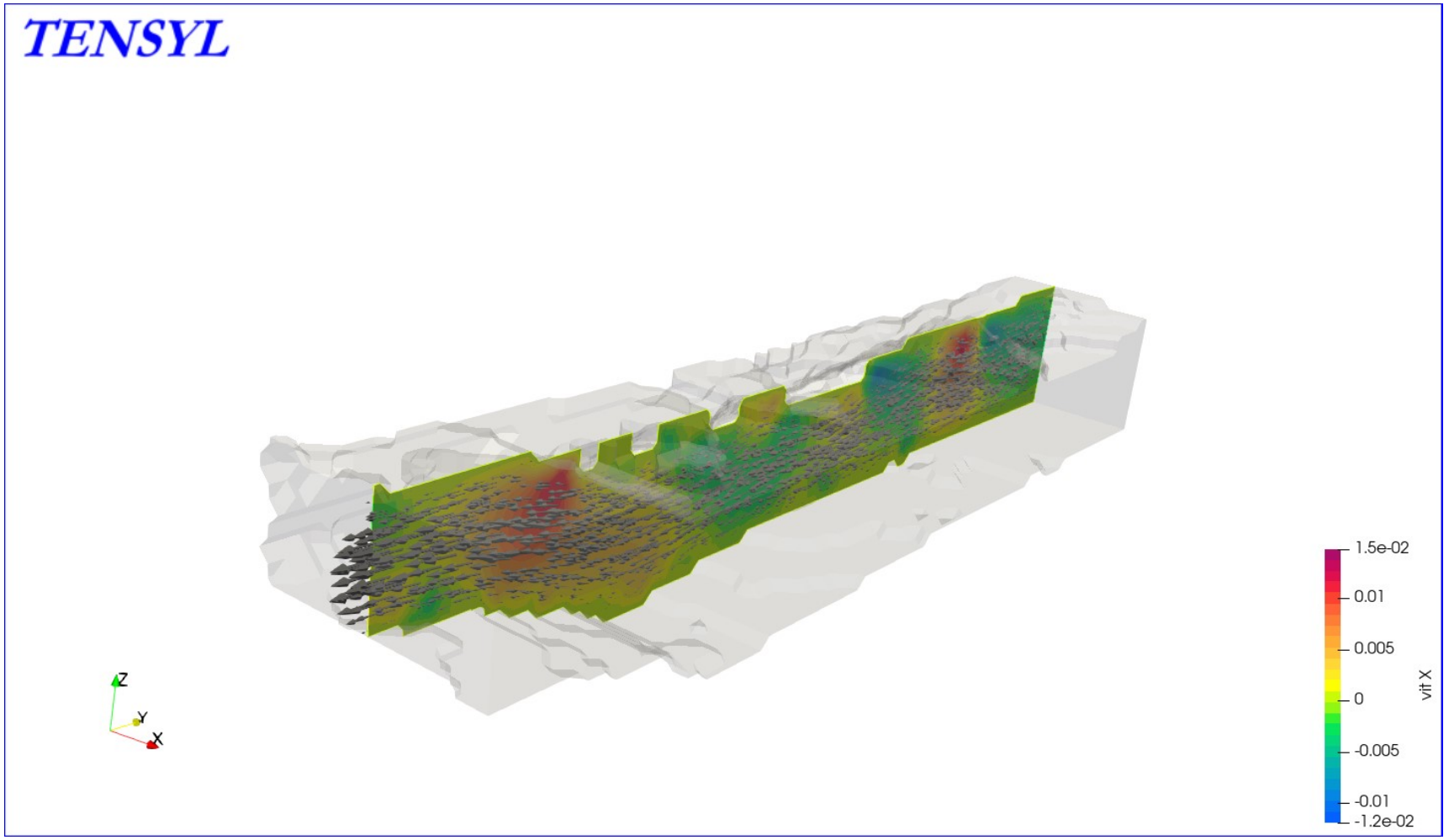
```
    fgmres 16523 Res:  = 1.01958e-06 Rel res = 1.01958e-06
    fgmres 16524 Res:  = 1.01939e-06 Rel res = 1.01939e-06
    fgmres 16525 Res:  = 1.01918e-06 Rel res = 1.01918e-06
    fgmres 16526 Res:  = 1.01824e-06 Rel res = 1.01824e-06
    fgmres 16527 Res:  = 1.01784e-06 Rel res = 1.01784e-06
    fgmres 16528 Res:  = 1.01778e-06 Rel res = 1.01778e-06
    fgmres 16529 Res:  = 1.01694e-06 Rel res = 1.01694e-06
    fgmres 16530 Res:  = 1.01643e-06 Rel res = 1.01643e-06
    fgmres 16531 Res:  = 1.01641e-06 Rel res = 1.01641e-06
    fgmres 16532 Res:  = 1.01565e-06 Rel res = 1.01565e-06
    fgmres 16533 Res:  = 1.01504e-06 Rel res = 1.01504e-06
    fgmres 16534 Res:  = 1.01504e-06 Rel res = 1.01504e-06
    fgmres 16535 Res:  = 1.0144e-06 Rel res = 1.0144e-06
    fgmres 16536 Res:  = 1.01369e-06 Rel res = 1.01369e-06
    fgmres 16537 Res:  = 1.01368e-06 Rel res = 1.01368e-06
    fgmres 16538 Res:  = 1.01314e-06 Rel res = 1.01314e-06
    fgmres 16539 Res:  = 1.01237e-06 Rel res = 1.01237e-06
    fgmres 16540 Res:  = 1.01231e-06 Rel res = 1.01231e-06
    fgmres 16541 Res:  = 1.01189e-06 Rel res = 1.01189e-06
    fgmres 16542 Res:  = 1.01102e-06 Rel res = 1.01102e-06
    fgmres 16543 Res:  = 1.01088e-06 Rel res = 1.01088e-06
    fgmres 16544 Res:  = 1.0106e-06 Rel res = 1.0106e-06
    fgmres 16545 Res:  = 1.00974e-06 Rel res = 1.00974e-06
    fgmres 16546 Res:  = 1.00953e-06 Rel res = 1.00953e-06
    fgmres 16547 Res:  = 1.00934e-06 Rel res = 1.00934e-06
    fgmres 16548 Res:  = 1.00845e-06 Rel res = 1.00845e-06
    fgmres 16549 Res:  = 1.00813e-06 Rel res = 1.00813e-06
    fgmres 16550 Res:  = 1.00804e-06 Rel res = 1.00804e-06
    fgmres 16551 Res:  = 1.00725e-06 Rel res = 1.00725e-06
    fgmres 16552 Res:  = 1.00679e-06 Rel res = 1.00679e-06
    fgmres 16553 Res:  = 1.00676e-06 Rel res = 1.00676e-06
    fgmres 16554 Res:  = 1.00606e-06 Rel res = 1.00606e-06
    fgmres 16555 Res:  = 1.00553e-06 Rel res = 1.00553e-06
    fgmres 16556 Res:  = 1.00553e-06 Rel res = 1.00553e-06
    fgmres 16557 Res:  = 1.00499e-06 Rel res = 1.00499e-06
    fgmres 16558 Res:  = 1.00435e-06 Rel res = 1.00435e-06
    fgmres 16559 Res:  = 1.00433e-06 Rel res = 1.00433e-06
    fgmres 16560 Res:  = 1.00392e-06 Rel res = 1.00392e-06
    fgmres 16561 Res:  = 1.00322e-06 Rel res = 1.00322e-06
    fgmres 16562 Res:  = 1.00315e-06 Rel res = 1.00315e-06
    fgmres 16563 Res:  = 1.00286e-06 Rel res = 1.00286e-06
    fgmres 16564 Res:  = 1.00219e-06 Rel res = 1.00219e-06
    fgmres 16565 Res:  = 1.00203e-06 Rel res = 1.00203e-06
    fgmres 16566 Res:  = 1.00185e-06 Rel res = 1.00185e-06
    fgmres 16567 Res:  = 1.00114e-06 Rel res = 1.00114e-06
    fgmres 16568 Res:  = 1.00091e-06 Rel res = 1.00091e-06
    fgmres 16569 Res:  = 1.00079e-06 Rel res = 1.00079e-06
    fgmres 16570 Res:  = 1.00011e-06 Rel res = 1.00011e-06
    fgmres 16571 Res:  = 9.99793e-07 Rel res = 9.99793e-07
    fgmres has converged in 16571 iterations The relative residual is 9.99793e-07
 cpu CGMatVirt 0 s / 0 nb mul
 cpu CGMatVirt 1129.83 s / 16589 nb mul
 Send plot:what: 7 0 773400 0.0162041 -0.0122039
 Send plot:what: 6 0 773400 1.16432 -0.047264
 u bound 1e+100 -1e+100  V : 1e+100 -1e+100
Plot bound [x,y] 0 0 max [x,y] 0 0
  Plot::  Sorry no ps version for this type of plot 7
  Plot::  Sorry no ps version for this type of plot 6
   iovtk writeMesh3: names  "vit"
   iovtk writeMesh3:value of iii=0 vit
 ## SetSolver 0x24ef776d770 0x24ef7685490 0
 cpu CGMatVirt 7.088 s / 33144 nb mul
    ~HashMatrix:   Mean collision in hash: 1.72948 0x24ef776d770 rank: 0 matmul 1129.81s
destroy mesh30x24ef7724ea0 destroy meshS 0
times: compile 0.082s, execution 6249.75s,  mpirank:0
```





A remplir

Post-traitement sur Paraview



A remplir

Rappel de la configuration de la machine

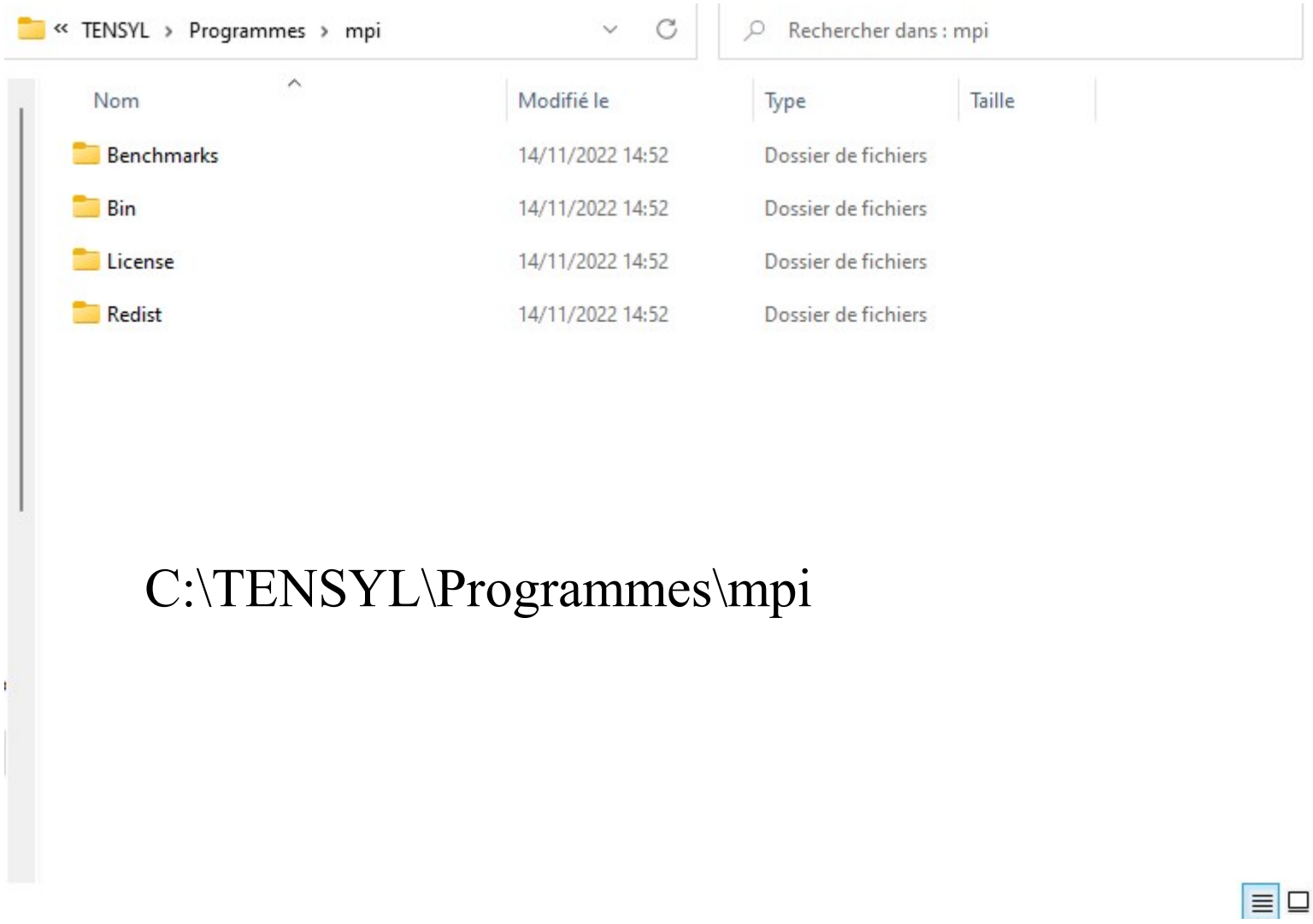
A remplir

Conclusions partielles

- La chaîne de traitement est fonctionnelle
- Le temps de calcul est prohibitif
- Le post-traitement sur Paraview est plutôt chiadé.

- ➔ On essaie maintenant d'implémenter Stokes en parallèle à l'aide de l'interface MPI / PETSc proposée par FreeFEM++.

Installation de MPI (commande mpiexec) sur Windows



C:\TENSYL\Programmes\mpi

Script d'exemple proposé par FreeFEM++

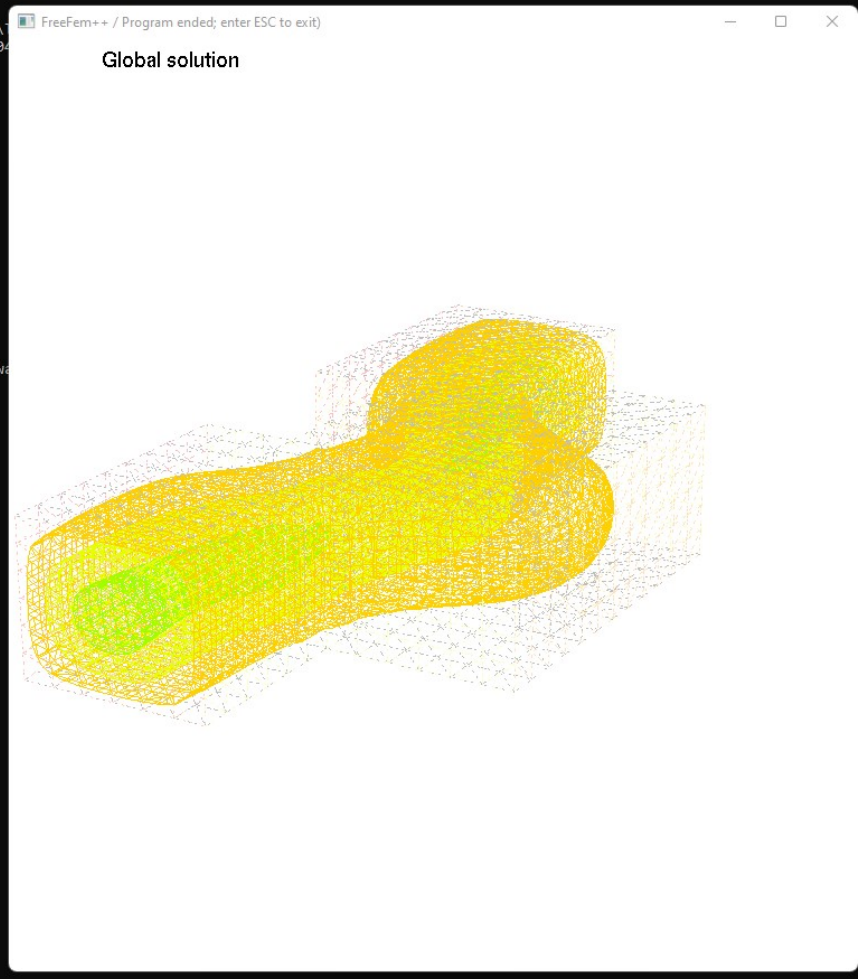
221114 > benchmark > exemple_stokes3D_petsc.edp

```
1  //  run with MPI:  ff-mpirun -np 4 script.edp
2  // NBPROC 4
3
4  load "PETSc"                        // PETSc plugin
5  macro dimension()3// EOM            // 2D or 3D
6  include "macro_ddm.idp"             // additional DDM functions
7
8  macro def(i)[i, i#B, i#C, i#D]//    // vector field definition
9  macro init(i)[i, i, i, i]// EOM     // vector field initialization
10 macro grad(u)[dx(u), dy(u), dz(u)]//// two-dimensional gradient
11 real Sqrt = sqrt(2.);
12 macro div(u)(dx(u) + dy(u#B) + dz(u#C))// EOM
13 func Pk = [P2, P2, P2, P1];         // finite element space
14
15 mesh3 Th;
16 {
17     mesh ThGlobal2d = square(getARGV("-global", 12), getARGV("-global", 12), [x, y]);    // global mesh
18     ThGlobal2d = trunc(ThGlobal2d, (x <= 0.5) || (y <= 0.5), label = 5);
19     ThGlobal2d = trunc(ThGlobal2d, (y >= 0.25) || (x >= 0.25), label = 5);
20     mesh Th2d = movemesh(ThGlobal2d, [-x, y]);
21     ThGlobal2d = ThGlobal2d + Th2d;
22     Th = buildlayers(ThGlobal2d, getARGV("-global", 12) / 2, zbound = [0, 0.4]);
23 }
24 Mat A;
25 buildMat(Th, getARGV("-split", 1), A, Pk, mpiCommWorld)
26
27 fespace Wh(Th, Pk);                 // local finite element space
28
29 varf vPb([u, uB, uC, p], [v, vB, vC, q])
30 = int3d(Th)(grad(u)' * grad(v) + grad(uB)' * grad(vB) + grad(uC)' * grad(vC) - div(u) * q - div(v) * p + 1e-10 * p * q)
31 + on(0, 1, 3, 5, u = 0, uB = 0, uC = 0)
32 + on(2, u = 1000*y*(0.5-y)*z*(0.4-z), uB = 0, uC = 0)
33 ;
34
35 real[int] rhs = vPb(0, Wh, tgv = -1);
36
37 set(A, sparams = "-pc_type lu");
38 Wh<real> def(u);
39
40 A = vPb(Wh, Wh, tgv = -1);
41 u[] = A^-1 * rhs;
42
43 macro def1(u)u// EOM
44 plotMPI(Th, u, P2, def1, real, cmm = "Global solution")
45
```

A remplir

Exécution du script dans un terminal externe

```
C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>C:\TENSYL\Programmes\mpi\bin\mpiexec -n 4 freefem++-mpi exemple_stokes3D_petsc.edp -ns -v 1 -wg
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : exemple_stokes3D_petsc.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue parallelempi
  -- Square mesh : nb vertices  =169 ,  nb triangles = 288 ,  nb boundary edges 48
  -- Square mesh : nb vertices  =169 ,  nb triangles = 288 ,  nb boundary edges 48
  -- Build Nodes/DF on mesh :   n.v. 1666, n. elmt. 7128, n b. elmt. 1836
     nb of Nodes 7128    nb of DoF   7128  DFon=0001
  -- FESpace: Nb of Nodes 7128 Nb of DoF 7128
  -- FESpace: Nb of Nodes 1666 Nb of DoF 1666
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\PETSc = 0)(load: loadLibary C:\
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3 = 0) sizestack + 1024 =9304

  -- Square mesh : nb vertices  =169 ,  nb triangles = 288 ,  nb boundary edges 48
  -- Square mesh : nb vertices  =169 ,  nb triangles = 288 ,  nb boundary edges 48
  -- Build Nodes/DF on mesh :   n.v. 1666, n. elmt. 7128, n b. elmt. 1836
     nb of Nodes 7128    nb of DoF   7128  DFon=0001
  -- FESpace: Nb of Nodes 7128 Nb of DoF 7128
  -- FESpace: Nb of Nodes 1666 Nb of DoF 1666
  -- Build Nodes/DF on mesh :   n.v. 1666, n. elmt. 7128, n b. elmt. 1836
     nb of Nodes 7128    nb of DoF   7128  DFon=0001
  -- Build Nodes/DF on mesh :   n.v. 1666, n. elmt. 7128, n b. elmt. 1836
  -- FESpace: Nb of Nodes 7128 Nb of DoF 7128
     nb of Nodes 7128    nb of DoF   7128  DFon=0001
  -- FESpace: Nb of Nodes 1666 Nb of DoF 1666
  -- FESpace: Nb of Nodes 7128 Nb of DoF 7128
  -- FESpace: Nb of Nodes 1666 Nb of DoF 1666
  -- FESpace: Nb of Nodes 525 Nb of DoF 525
  -- FESpace: Nb of Nodes 525 Nb of DoF 525
 --- global mesh of 7128 elements (prior to refinement) partitioned with metis  --metis↔OA: 4-wa
 (in 1.506340e-02)
  -- FESpace: Nb of Nodes 697 Nb of DoF 697
  -- FESpace: Nb of Nodes 483 Nb of DoF 483
  -- FESpace: Nb of Nodes 700 Nb of DoF 700
  -- FESpace: Nb of Nodes 483 Nb of DoF 483
  -- Build Nodes/DF on mesh :   n.v. 525, n. elmt. 2070, n b. elmt. 626
     nb of Nodes 2070    nb of DoF   2070  DFon=0001
  -- FESpace: Nb of Nodes 2070 Nb of DoF 2070
  -- Build Nodes/DF on mesh :   n.v. 525, n. elmt. 2070, n b. elmt. 626
     nb of Nodes 2070    nb of DoF   2070  DFon=0001
  -- FESpace: Nb of Nodes 2070 Nb of DoF 2070
  -- Build Nodes/DF on mesh :   n.v. 483, n. elmt. 1908, n b. elmt. 572
     nb of Nodes 3159    nb of DoF   9960  DFon=4300
  -- Build Nodes/DF on mesh :   n.v. 483, n. elmt. 1908, n b. elmt. 572
     nb of Nodes 3159    nb of DoF   9960  DFon=4300
  -- FESpace: Nb of Nodes 3159 Nb of DoF 9960
  -- FESpace: Nb of Nodes 3159 Nb of DoF 9960
  -- Build Nodes/DF on mesh :   n.v. 98, n. elmt. 252, n b. elmt. 172
  -- Build Nodes/DF on mesh :   n.v. 98, n. elmt. 252, n b. elmt. 172
     nb of Nodes 533    nb of DoF   1697  DFon=4300
     nb of Nodes 533    nb of DoF   1697  DFon=4300
  -- FESpace: Nb of Nodes 533 Nb of DoF 1697
  -- FESpace: Nb of Nodes 533 Nb of DoF 1697
  -- Build Nodes/DF on mesh :   n.v. 483, n. elmt. 1908, n b. elmt. 572
  -- Build Nodes/DF on mesh :   n.v. 483, n. elmt. 1908, n b. elmt. 572
     nb of Nodes 3159    nb of DoF   9960  DFon=4300
     nb of Nodes 3159    nb of DoF   9960  DFon=4300
  -- FESpace: Nb of Nodes 3159 Nb of DoF 9960
  -- FESpace: Nb of Nodes 3159 Nb of DoF 9960
  -- FESpace: Nb of Nodes 576 Nb of DoF 576
  -- Build Nodes/DF on mesh :   n.v. 697, n. elmt. 2853, n b. elmt. 888
  -- FESpace: Nb of Nodes 570 Nb of DoF 570
     nb of Nodes 2853    nb of DoF   2853  DFon=0001
  -- FESpace: Nb of Nodes 2853 Nb of DoF 2853
  -- Build Nodes/DF on mesh :   n.v. 700, n. elmt. 2857, n b. elmt. 896
```



Script parallèle de résolution de Stokes - Poiseuille

221114 > benchmark > main_petsc.edp

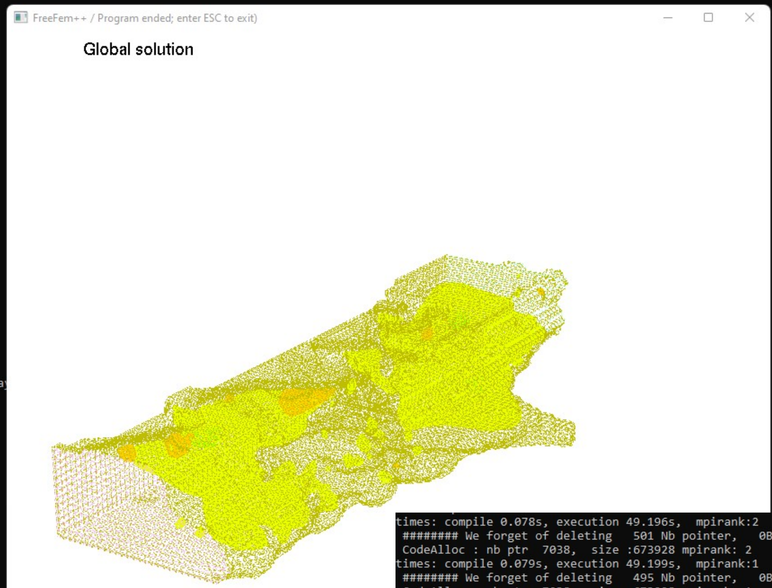
```
load "gmsh"
load "iovtk"
load "msh3"
load "PETSc"
macro dimension()3 // EOM    // 2D or 3D
include "macro_ddm.idp"
int[int] ordre = [1];

macro def(i)[i, i#B, i#C, i#D] // EOM    // definition d'un champ de vecteurs
macro init(i)[i, i, i, i] // EOM    // initialisation d'un champ de vecteur
macro grad(w)[dx(w), dy(w), dz(w)] // EOM    // gradient de la grandeur scalaire w
macro div(w)(dx(w) + dy(w#B) + dz(w#C)) // EOM    // divergence du champ de vecteur w

func Pk = [P2, P2, P2, P1];    // espace d'interpolation de Taylor-Hood

mesh3 Th;
int inflow = 10;     // label du bord d'entree
int outflow = 20;    // label du bord de sortie
int noslip = 30;     // label du bord impermeable
{
    Th = gmshload3("gmsh_img_RE_G_100_4_ascii_without_parametric_Clean.msh");    // lecture du maillage

    real[int] bb(6);    // vecteur des valeurs min et max de chaque axe
    boundingbox(Th, bb);    // remplissage du vecteur
    real eps = (bb[3]-bb[2])*0.1/100;    // tolerance numerique de detection des bords du maillage



    func newlab = (y < bb[2]+eps) ? inflow : (y > bb[3]-eps ? outflow : noslip);    // association du label par critere de position

    Th = change(Th, flabel=newlab);    // application de newlab() aux noeuds du maillage
}

Mat A;    // declaration de l'operateur distribue
buildMat(Th, getARGV("-split", 1), A, Pk, mpiCommWorld)    // construction de l'operateur distribue

fespace Wh(Th, Pk);    // espace d'interpolation local (Pk : fonction contenant la liste des bases d'interpolation par composante)

// Formulation faible du probleme de Stokes avec C.L en pression pour Stokes stationnaire
varf stokes([ux, uy, uz, p], [vx, vy, vz, q])
= int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz] )
+ on(noslip, ux=0, uy=0, uz=0)
+ on(inflow, p=1)
+ on(outflow, p=0)
;

real[int] rhs = stokes(0, Wh);    // affectation du second membre

set(A, sparams = "-pc_type lu");
Wh<real> def(u);

A = stokes(Wh, Wh);    // affectation de l'operateur
u[] = A^-1 * rhs;    // resolution du systeme lineaire

macro def1(u)u // EOM    // macro de definition adaptee aux environnements paralleles
plotMPI(Th, u, P2, def1, real, cmm="Global solution")    // appel de la macro d'affichage adaptee aux environnements paralleles

```

A remplir

Sortie du script, exécution 50 secondes

Le solver est resté factorisation « LU », comme dans l'exemple

```
C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>C:\TENSYL\Programmes\mpi\bin\mpiexec -n 4 freefem++-mpi main_petsc.edp -ns -v 1 -wg
-- FreeFem++ v4.11 (Thu, Apr 07, 2022  2:25:37 PM - git v4.11)
   file : main_petsc.edp
 Load: lg_fem lg_mesh lg_mesh3 eigenvalue parallelempi
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\gmsh = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\iovtk = 0) load: iovtk
(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\msh3 = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\PETSc = 0)(load: loadLibary C:\TENSYL\Programmes\Freefem_411\FreeFem++\\.\metis = 0) load: init meti
s (v  5 )
 (already loaded: msh3) sizestack + 1024 =8848  ( 7824 )

77340 tetrahedrons
22524 triangles
99864 numElements
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 77340    nb of DoF   77340  DFon=0001
  -- FESpace: Nb of Nodes 77340 Nb of DoF 77340
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
77340 tetrahedrons
22524 triangles
99864 numElements
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 77340    nb of DoF   77340  DFon=0001
  -- FESpace: Nb of Nodes 77340 Nb of DoF 77340
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
77340 tetrahedrons
22524 triangles
99864 numElements
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 77340    nb of DoF   77340  DFon=0001
  -- FESpace: Nb of Nodes 77340 Nb of DoF 77340
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
77340 tetrahedrons
22524 triangles
99864 numElements
  -- Build Nodes/DF on mesh :   n.v. 18337, n. elmt. 77340, n b. elmt. 22524
     nb of Nodes 77340    nb of DoF   77340  DFon=0001
  -- FESpace: Nb of Nodes 77340 Nb of DoF 77340
  -- FESpace: Nb of Nodes 18337 Nb of DoF 18337
  -- FESpace: Nb of Nodes 5445 Nb of DoF 5445
 --- global mesh of 77340 elements (prior to refinement) partitioned with metis  --metis←OA: 4-way
 (in 1.972940e-01)
  -- FESpace: Nb of Nodes 5373 Nb of DoF 5373
  -- FESpace: Nb of Nodes 5757 Nb of DoF 5757
  -- FESpace: Nb of Nodes 6011 Nb of DoF 6011
  -- FESpace: Nb of Nodes 5123 Nb of DoF 5123
  -- Build Nodes/DF on mesh :   n.v. 5445, n. elmt. 22238, n b. elmt. 6988
     nb of Nodes 22238    nb of DoF   22238  DFon=0001
  -- FESpace: Nb of Nodes 22238 Nb of DoF 22238
  -- FESpace: Nb of Nodes 5049 Nb of DoF 5049
  -- Build Nodes/DF on mesh :   n.v. 5373, n. elmt. 22048, n b. elmt. 6832
     nb of Nodes 22048    nb of DoF   22048  DFon=0001
  -- FESpace: Nb of Nodes 22048 Nb of DoF 22048
  -- FESpace: Nb of Nodes 5125 Nb of DoF 5125
  -- Build Nodes/DF on mesh :   n.v. 5757, n. elmt. 23953, n b. elmt. 7144
     nb of Nodes 23953    nb of DoF   23953  DFon=0001
  -- FESpace: Nb of Nodes 23953 Nb of DoF 23953
  -- FESpace: Nb of Nodes 5411 Nb of DoF 5411
  -- Build Nodes/DF on mesh :   n.v. 6011, n. elmt. 24715, n b. elmt. 7584
     nb of Nodes 24715    nb of DoF   24715  DFon=0001
  -- FESpace: Nb of Nodes 24715 Nb of DoF 24715
  -- Build Nodes/DF on mesh :   n.v. 5123, n. elmt. 20781, n b. elmt. 6638
     nb of Nodes 34345    nb of DoF   108158  DFon=4300
  -- FESpace: Nb of Nodes 34345 Nb of DoF 108158
  -- Build Nodes/DF on mesh :   n.v. 5049, n. elmt. 20731, n b. elmt. 6418
     nb of Nodes 34037    nb of DoF   107160  DFon=4300
  -- Build Nodes/DF on mesh :   n.v. 843, n. elmt. 2692, n b. elmt. 1342
     nb of Nodes 5048    nb of DoF   15987  DFon=4300
```




```
times: compile 0.078s, execution 49.196s,  mpirank:2
 ######## We forget of deleting   501 Nb pointer,   0Bytes  ,  mpirank 2, memory leak =0
 CodeAlloc : nb ptr  7038,  size :673928 mpirank: 2
times: compile 0.079s, execution 49.199s,  mpirank:1
 ######## We forget of deleting   495 Nb pointer,   0Bytes  ,  mpirank 1, memory leak =0
 CodeAlloc : nb ptr  7038,  size :673928 mpirank: 1
times: compile 0.078s, execution 49.228s,  mpirank:3
 ######## We forget of deleting   441 Nb pointer,   0Bytes  ,  mpirank 3, memory leak =0
 CodeAlloc : nb ptr  7038,  size :673928 mpirank: 3
  Plot::  Sorry no ps version for this type of plot 106
  Plot::  Sorry no ps version for this type of plot 106
  Plot::  Sorry no ps version for this type of plot 106
  Plot::  Sorry no ps version for this type of plot 106
times: compile 7.800000e-02s, execution 4.976000e+01s,  mpirank:0
 ######## We forget of deleting   489 Nb pointer,   0Bytes  ,  mpirank 0, memory leak =0
 CodeAlloc : nb ptr  7038,  size :673928 mpirank: 0
Ok: Normal End

C:\Users\jvalentin\Desktop\WORKSPACE\221114\benchmark>
```

Adaptation à l'export .vtu des grandeurs calculées (\vec{u}, p)

221114 > benchmark > main_petsc.edp

```
1   load "gmsh"
2   load "iovtk"
3   load "msh3"
4   load "PETSc"
5   macro dimension()3 // EOM    // 2D or 3D
6   include "macro_ddm.idp"
7   int[int] ordre = [1];
8
9   macro def(i)[i, i#x, i#y, i#z] // EOM    // definition d'un champ de vecteurs
10  macro init(i)[i, i, i, i] // EOM    // initialisation d'un champ de vecteur
11  macro grad(w)[dx(w), dy(w), dz(w)] // EOM    // gradient de la grandeur scalaire w
12
13  func Pk = [P2, P2, P2, P1];    // espace d'interpolation de Taylor-Hood
14
15  mesh3 Th;
16  int inflow = 10;     // label du bord d'entree
17  int outflow = 20;    // label du bord de sortie
18  int noslip = 30;     // label du bord impermeable
19  {
20      Th = gmshload3("gmsh_img_RE_G_100_4_ascii_without_parametric_Clean.msh");    // lecture du maillage
21
22      real[int] bb(6);    // vecteur des valeurs min et max de chaque axe
23      boundingbox(Th, bb);    // remplissage du vecteur
24
25      real eps = (bb[3]-bb[2])*0.1/100;    // tolerance numerique de detection des bords du maillage
26
27      func newlab = (y < bb[2]+eps) ? inflow : (y > bb[3]-eps ? outflow : noslip);    // association du label par critere de position
28
29      Th = change(Th, flabel=newlab);    // application de newlab() aux noeuds du maillage
30  }
31
32  Mat A;    // declaration de l'operateur distribue
33  buildMat(Th, getARGV("-split", 1), A, Pk, mpiCommWorld)    // construction de l'operateur distribue
34
35  fespace Wh(Th, Pk);    // espace d'interpolation local (Pk : fonction qui renvoie le vecteur des bases d'interpolation)
36  fespace Vh(Th, P2);    // espace d'interpolation local (interpolation composante par composante du vecteur vitesse)
37  fespace Ph(Th, P1);    // espace d'interpolation local (interpolation de la pression)
38
39  // Formulation faible du probleme de Stokes avec C.L en pression pour Stokes stationnaire
40  varf stokes([ux, uy, uz, p], [vx, vy, vz, q])
41  = int3d(Th)( grad(ux)'*grad(vx) + grad(uy)'*grad(vy) + grad(uz)'*grad(vz) - grad(p)'*[vx,vy,vz] - grad(q)'*[ux,uy,uz] )
42  + on(noslip, ux=0, uy=0, uz=0)
43  + on(inflow, p=1)
44  + on(outflow, p=0)
45  ;
46
47  real[int] rhs = stokes(0, Wh);    // affectation du second membre
48
49  set(A, sparams = "-pc_type lu");
50  Wh<real> def(u);
51
52  A = stokes(Wh, Wh);    // affectation de l'operateur
53  u[] = A^-1 * rhs;    // resolution du systeme lineaire
54
55  macro def1(u) u // EOM    // macro d'extraction de la premiere composante du vecteur u
56  macro def2(u) [u, u#x, u#y] // EOM    // macro d'extraction des trois premieres composantes du vecteur u
57  macro def3(u) u#z // EOM    // macro d'extraction de la quatrieme composante du vecteur u
58
59  plotMPI(Th, u, P2, def1, real, cmm="Global solution")    // appel de la macro d'affichage adaptee aux environnements paralleles
60  // plotMPI(Th, def2(u), [P2,P2,P2], def2, real, cmm="Vitesse")    // macro d'affichage du champ de vecteurs vitesse
61
62  // if(mpirank == 0) {
63      // savevtk("petsc_vit.vtu", Th, [u, ux, uy], dataname="vit", order=ordre);
64      // savevtk("petsc_pre.vtu", Th, [uz, 0.0, 0.0], dataname="pre", order=ordre);
65  // }
66
```

- Cette implémentation fonctionne : la sortie est l'affichage de la première composante du vecteur vitesse en tant que grandeur scalaire.

- Dé-commenter la ligne 60 : levée de l'erreur :

current line = 103 mpirank 1 / 4
Error line number 103, in file macro: plotMPI in C:\TENSYL\Programmes\Freefem_411\FreeFem++\\idp\macro_ddm.idp, before token)
plot of array with wrong number of components (!= 2 or 3)
current line = 103 mpirank 0 / 4
Compile error : plot of array with wrong number of components (!= 2 or 3)
line number :103,)
error Compile error : plot of array with wrong number of components (!= 2 or 3)
line number :103,)
code = 1 mpirank: 0

- De même, les lignes 62 – 65 lèvent des erreurs

Retour aux sources : l'exemple hpddm/stokes-2d-PETSc.edp

```
8   macro def(i)[i, i#B, i#C]// EOM     // vector field definition
9   macro init(i)[i, i, i]// EOM        // vector field initialization
10  macro grad(u)[dx(u), dy(u)]// EOM   // two-dimensional gradient
11  real Sqrt = sqrt(2.);
12  macro epsilon(u)[dx(u), dy(u#B), (dy(u) + dx(u#B)) / Sqrt]// EOM
13  macro div(u)(dx(u) + dy(u#B))// EOM
14  func Pk = [P2, P2, P1];             // finite element space
```

```
36  macro def2(u)[u, u#B]// EOM
37  macro def1(u)u// EOM
38  plotMPI(Th, def2(u), [P2, P2], def2, real, cmm = "Global velocity")
39  plotMPI(Th, uC, P1, def1, real, cmm = "Global pressure")
```

A remplir

Bibliographie