Exercises

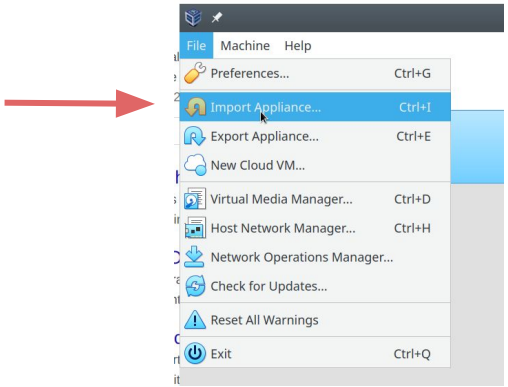
Félix Kwok, Eric Chamberland, Dave Martin

june 1st 2021

Université Laval

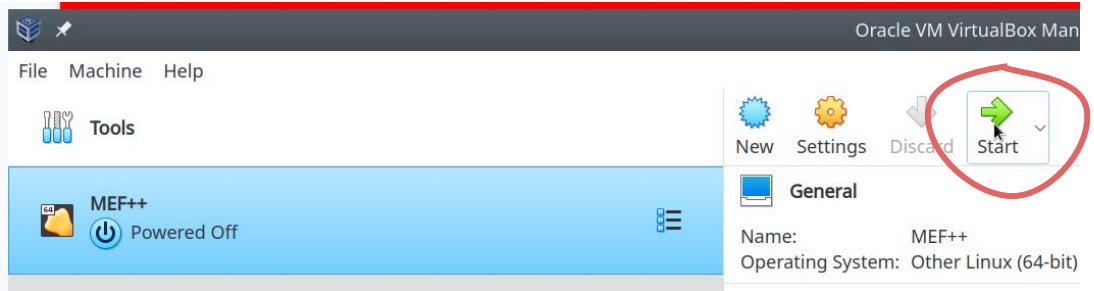
Preparation

1. Install VirtualBox software on your machine:
   https://www.virtualbox.org/
2. Download MEF++ virtual machine archive (4.4 Gb):
   https://giref.ulaval.ca/~ericc/crm/vm_crm.ova
3. Open VirtualBox and import the .ova VM file (you need 10 Gb more on your disk):



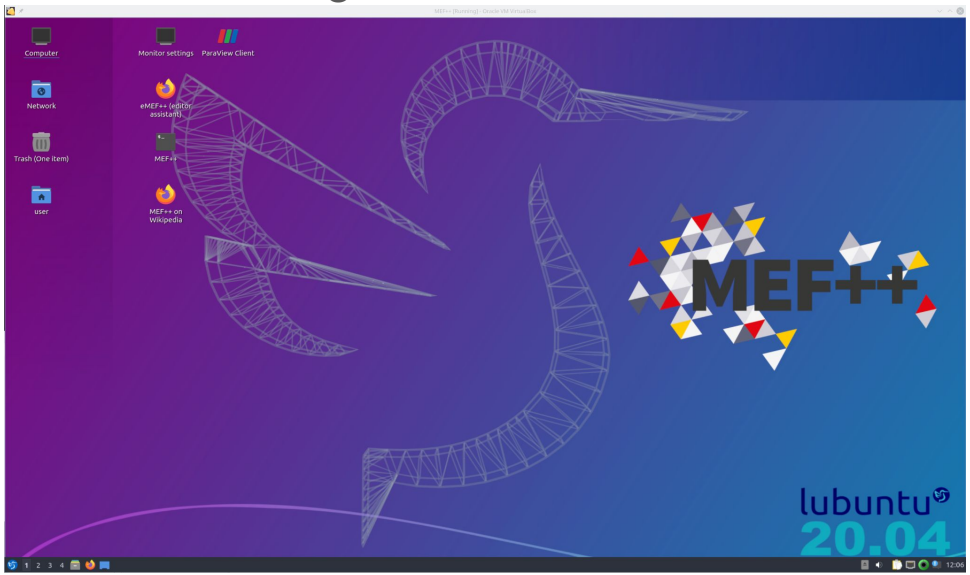
Preparation

4. Start the VM:



Preparation

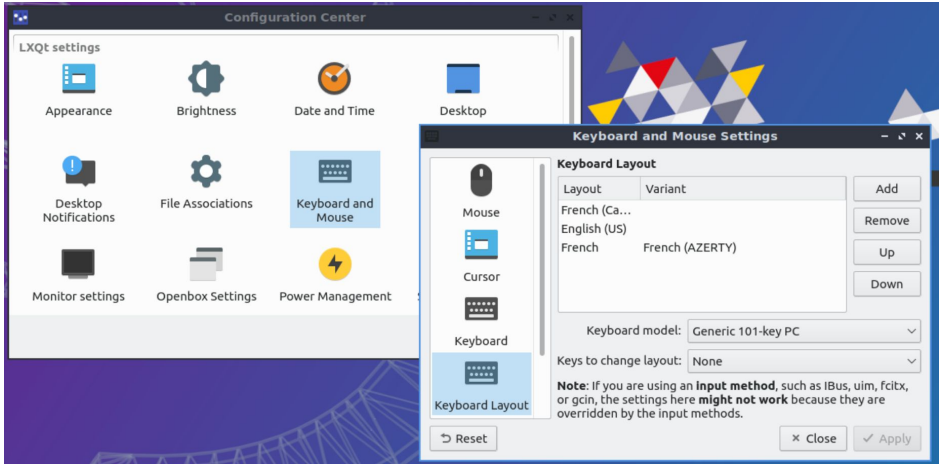
5. You should have something like this:



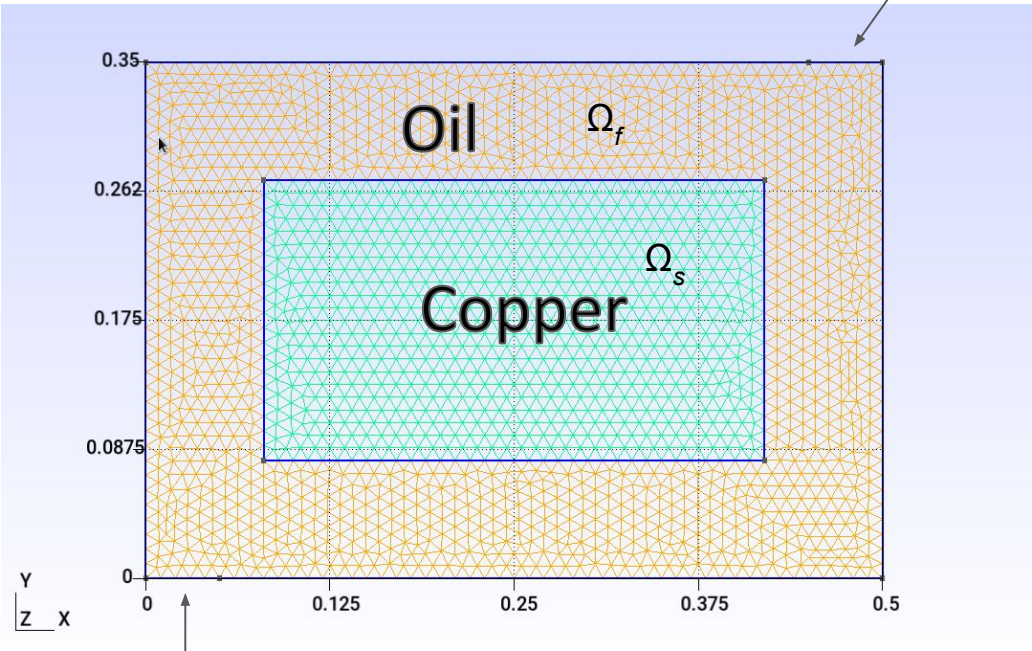
Preparation

6. featherpad is there, but you may want to install your preferred editor.
   ex: sudo apt install kate

7. Change your keyboard layout:



Transformateur



Conservation laws – steady state

Assuming that a steady state solution can be reached, we can set all time-derivative terms to zero and get

$$
\begin{aligned}
&\text{Momentum :} && \nabla \cdot (2\eta \nabla^s \mathbf{v}) - \rho_f (\mathbf{v} \cdot \nabla)\mathbf{v} - \nabla p = 0 && \text{in } \Omega_f, \\
&\text{Mass :} && \nabla \cdot (\rho_f \mathbf{v}) = 0 && \text{in } \Omega_f, \\
&\text{Heat :} && -\nabla \cdot (K_f \nabla T) + \nabla \cdot (\mathbf{v}\, \rho_f C_f T) = 0 && \text{in } \Omega_f, \\
&\text{Heat :} && -\nabla \cdot (K_s \nabla T) = q && \text{in } \Omega_s, \\
&\text{Coupling :} && K_s \nabla T \cdot \mathbf{n}_s + K_f \nabla T \cdot \mathbf{n}_f = 0 && \text{on } \Gamma.
\end{aligned}
$$

Here, there are different physics within each region,

- Navier-Stokes on Ω_f (coupling to T via ρ and η),
- Diffusion on Ω_s (coupled to T in Ω_f),
- Advection-diffusion on Ω_f (coupled to T in Ω_f and to $\mathbf{v}$ in N-S).

Exercise #0 : warm up.

First launch the MEF++ terminal, then type:

```
MEF++ transformateur |& tee out.txt
```

all the output to your screen is also redirected to the `out.txt` file.

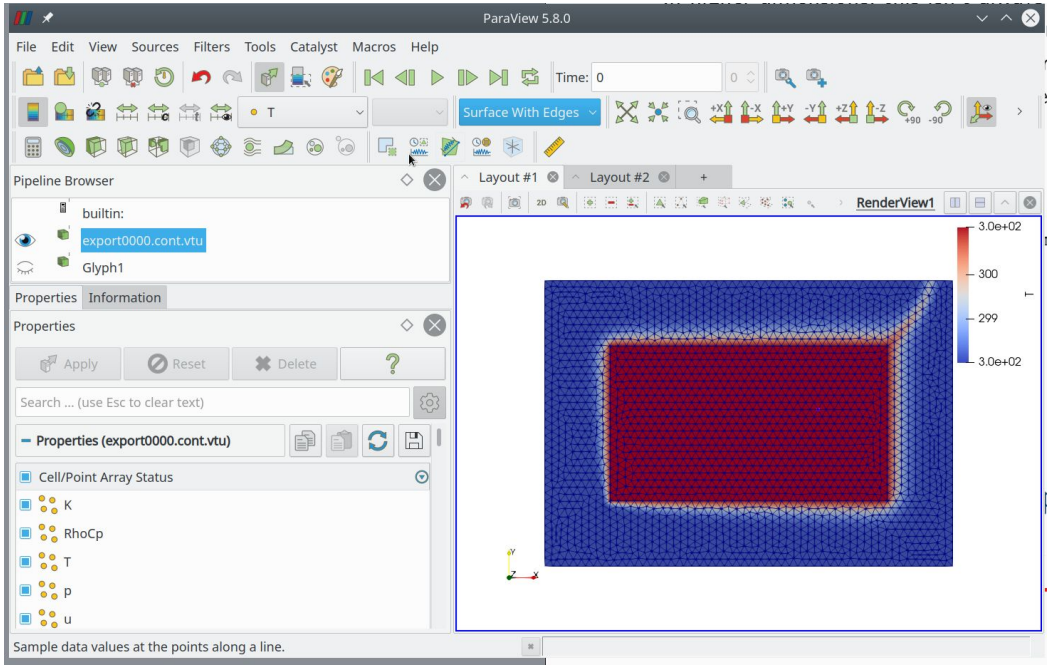
Have a look at produced files (in user/CRM). You should find a file named:

```
export0000.cont.vtu
```

Open it with `paraview` to see the results.

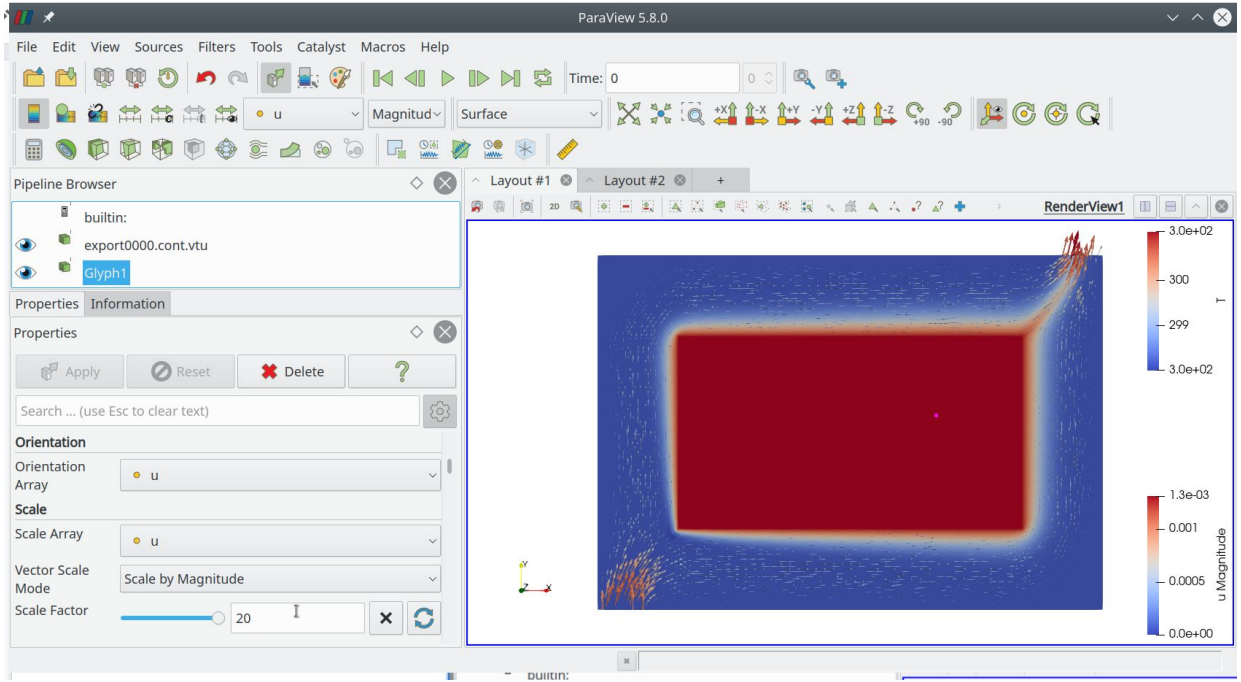
Paraview

Temperature field:



Paraview

Velocity field:



Exercise #1A :

In MEF++ terminal, launch your editor on transformateur.champs file:

```
featherpad transformateur.champs
```

Let's have a deeper look at the solver used. Uncomment (remove '#'):

```
ksp_view
```

In "GrosLU" options, then launch again:

```
MEF++ transformateur |& tee out.txt
```

Q: Look in out.txt. What is the ratio of non-zeros in the factored matrix vs assembled?

Exercise #1B :

Let's ask to "draw" the matrix in the "GrosLU" options:

```
mat_view              draw
```

then launch again:

```
MEF++ transformateur |& tee out.txt
```

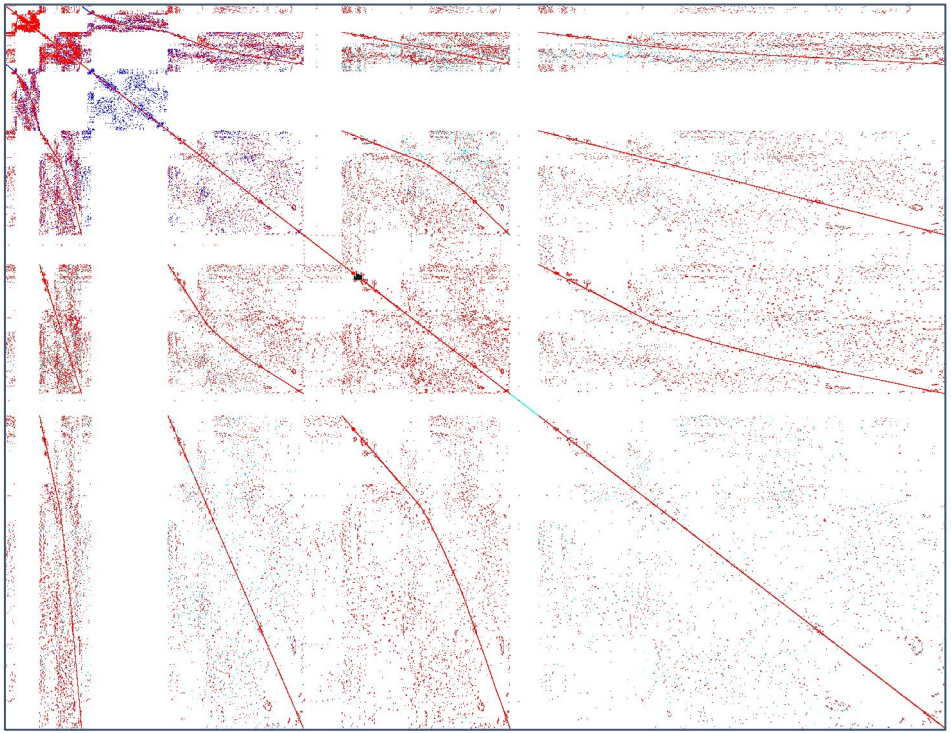
To pause the drawings and explore the matrix:

```
echo "draw_pause      -1" > .petsrc
```

1. Left click : zoom in
2. Middle click: zoom out
3. Right click: continue execution

Default Matrix: one block

U + P + T (mixed)



red : positive value
blue: negative value
cyan: zero value
white: nothing at all

Exercise #2A : 2x2 Blocks Matrix

Let's comment:

```
/* problemeef ProbEF
{ solveur_nlin SolveurStat(ProbEF)
    prefixe_options GrosLU
} */
```

And uncomment:

```
problemeef ProbEF [defaut, defaut,[(u*,p*),T]]
{ solveur_nlin SolveurStat(ProbEF)
    prefixe_options Blocs_2x2
}
```

Then launch MEF++:

```
MEF++ transformateur |& tee bjacobi.txt
```

Q: How many iterations are done for the first two Newton steps?

Exercise #2B : 2x2 Blocks Matrix

Let's have a deeper look at the solver used. Uncomment:

```
ksp_view
```

In "`Blocs_2x2`" options section, then launch again:

```
MEF++ transformateur |& tee bjacobi.txt
```

Q: What are the a_00 and a_11 matrices sizes?

Exercise #2C : 2x2 Blocks Matrix

Let's ask to "draw" the matrix in the "Blocks_2x2" options section:

```
mat_view            draw
```

then launch again:

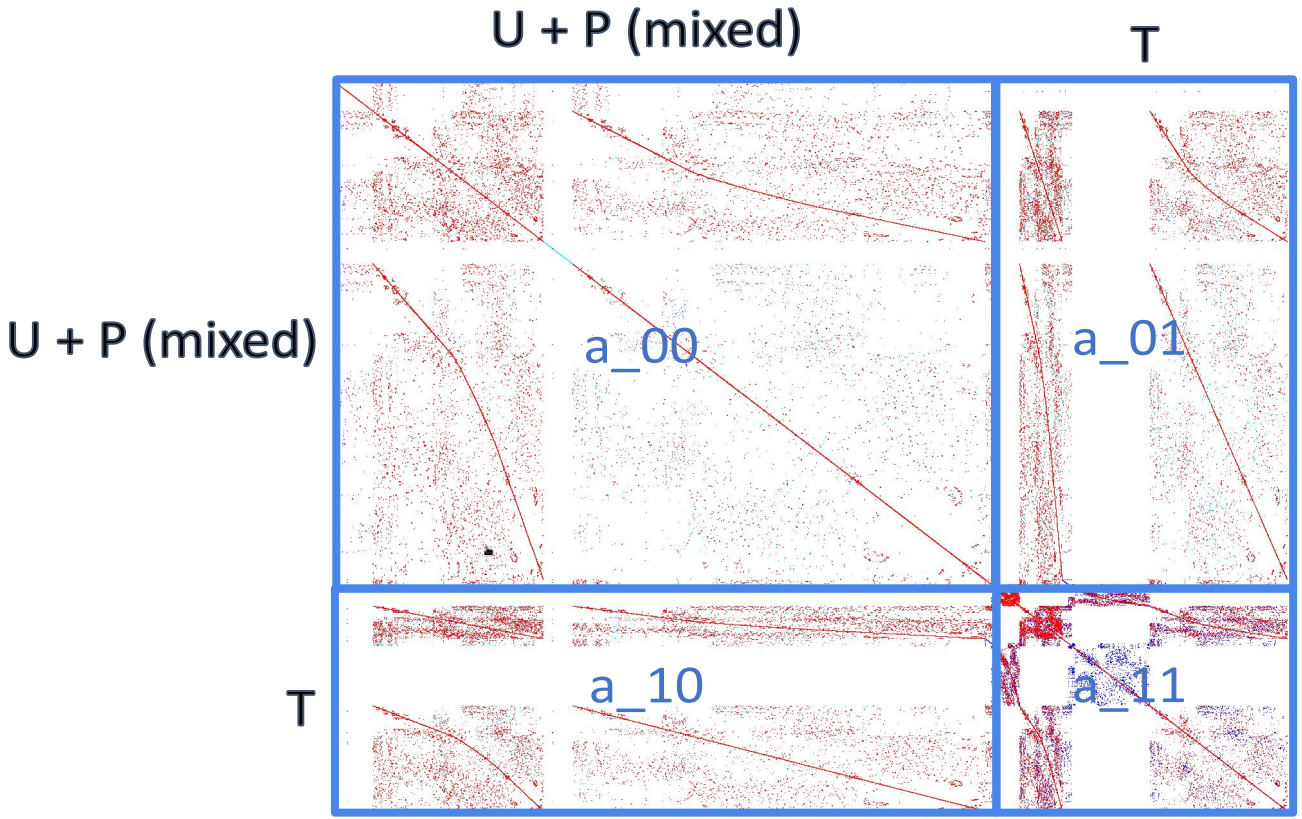
```
MEF++ transformateur
```

To pause the drawings and explore the matrix:

```
echo "draw_pause      -1" > .petsrc
```

1. Left click : zoom in
2. Middle click: zoom out
3. Right click: continue execution

2x2 block Matrix



red : positive value
blue: negative value
cyan: zero value
white: nothing at all

Exercise #2D : 2x2 Blocks Matrix

Let's switch from block Jacobi to Gauss-Seidel. Uncomment:

```
pc_fieldsplit_type                multiplicative
```

In "`Blocs_2x2`" options section, then launch:

```
MEF++ transformateur |& tee gauss_seidel.txt
```

Q: How many iterations are done for the first two Newton steps?

Exercise #2E : 2x2 Blocks Matrix

Let’s switch from block Gauss-Seidel to the symmetric version.

Uncomment:

```
pc_fieldsplit_type                symmetric_multiplicative
```

In “`Blocs_2x2`” options section, then launch:

```
MEF++ transformateur |& tee gauss_seidel_sym.txt
```

Q: How many iterations are done for the first two Newton steps?

Exercise #3A : Nested 2x2 Blocks Matrix

Let's comment:

```
/*problemeef ProbEF [defaut, defaut,[u*,p*),T]]
{ solveur_nlin SolveurStat(ProbEF)
    prefixe_options Blocs_2x2
}*/
```

And uncomment:

```
problemeef ProbEF [defaut, defaut,[ [u*,p*],T]]
{ solveur_nlin SolveurStat(ProbEF)
    prefixe_options Blocs_2x2_nested_in_2x2
}
```

Then launch MEF++:

```
MEF++ transformateur |& tee gauss_seidel_schur_u.txt
```

Q: How many iterations are done for the first two Newton steps?

Exercise #3B : Nested 2x2 Blocks Matrix

Let's have a deeper look at the solver used. Uncomment:

```
ksp_view
```

In "`Blocs_2x2_nested_in_2x2`" options section, then launch again:

```
MEF++ transformateur |& tee  gauss_seidel_schur_u.txt
```

Q: What are the sizes of :

- u,u block
- p,p block
- T,T block

Exercise #3C : Nested 2x2 Blocks Matrix

Let's ask to "draw" the matrix in the "`Blocs_2x2_nested_in_2x2`" options section:

```
mat_view                draw
```

then launch again:

```
MEF++ transformateur
```

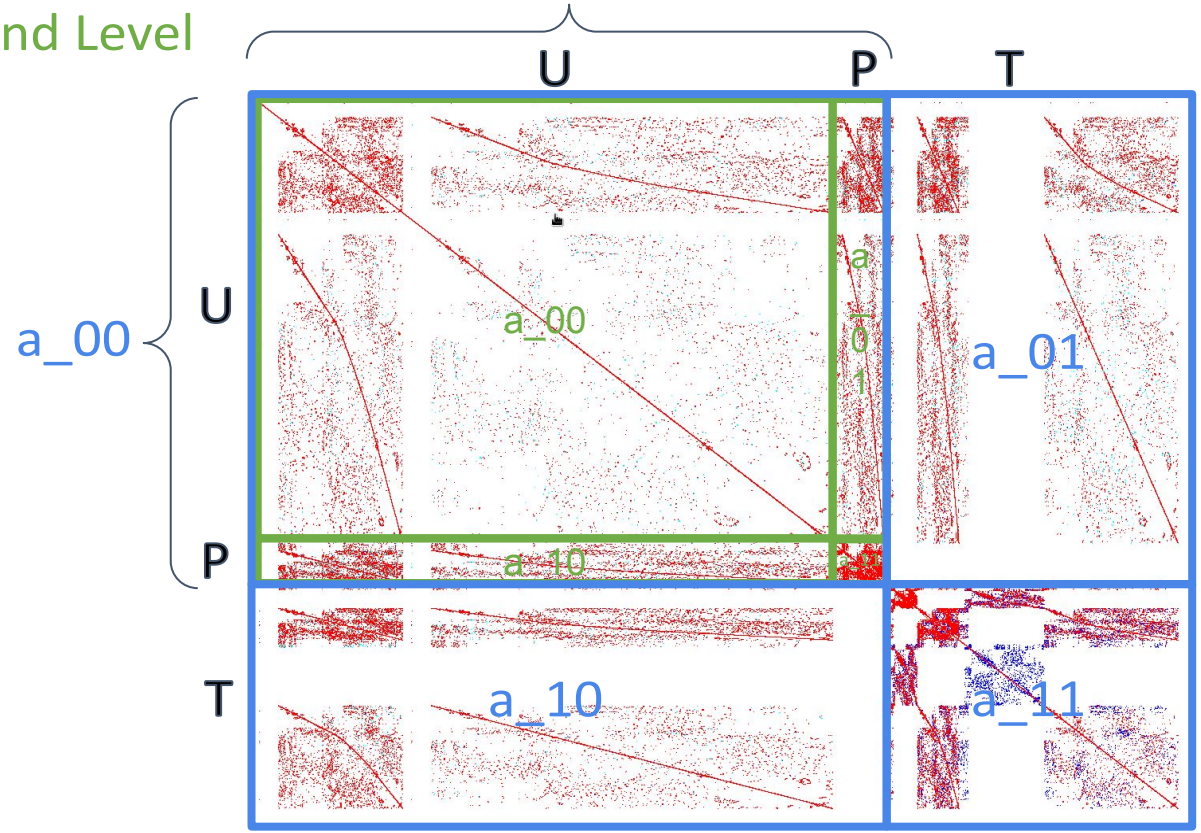
To pause the drawings and explore the matrix:

```
echo "draw_pause      -1" > .petsrc
```

1. Left click : zoom in
2. Middle click: zoom out
3. Right click: continue execution

Nested Matrix: 2x2 into a_00

First Level
Second Level



red : positive value
blue: negative value
cyan: zero value
white: nothing at all

Timings!

Have a look at the chrono.txt file:

```
...
[0]Temps de profiling "usager"
[0] Total    sec(WC) s(SelfUser) s(SelfSys) s(ChildUser) s(ChildSys) (VmSizeDiff , VmRSSDiff, VmDataDiff) nbApls      Etiquette
[0] Total     11.5219     18.2306      0.8974      0.0000      0.0000    475024 KB     60804 KB    120740 KB    1 x  Prog_complet.
...
[0] Total      1.6031      1.3676      0.0201      0.2101      0.0000      1092 KB       912 KB         4 KB    9 x    SolveurStatNlinPETSc::faisAssemblage:ProbEF.
...
[0] Total      9.4742     16.5479      0.7756      0.0000      0.0000    133968 KB     59104 KB     69140 KB    9 x    SolveurStatNlinPETSc::resoudre_et_RechercheLineaire:ProbEF.
```

Q: What's strange?

Timings!

You can limit the number of threads before comparing results:

```
export MKL_NUM_THREADS=1
```

Run again the same MEF++ command you did for the last computation...

Then, look at `chrono.txt` file:

```
[0]Temps de profiling "usager"

[0] Total     sec(WC) s(SelfUser) s(SelfSys) s(ChildUser) s(ChildSys) (VmSizeDiff , VmRSSDiff, VmDataDiff) nbApls      Etiquette

[0] Total     11.2302     10.7777     0.1157      0.0000      0.0000   367804 KB     60220 KB     78352 KB    1 x  Prog_complet.
```

A New Mesh!

Look at the mesh files in the “CRM” directory:

```
ls -la *.mail
```

The mesh used, transformateur.mail has the following components:

- 2186 nodes
- 6385 edges
- 4200 triangles

There is a second mesh, transformateur.mail.2 as follows:

- 8571 nodes
- 25370 edges
- 16800 triangles

A New Mesh!

From the MEF++ qterminal, copy the big mesh over the small one:

```
cp transformateur.mail.2 transformateur.mail
```

Now, you can do the exercices again and see the differences in size, but also in timings.

Going further

See all iterative methods available:

https://www.mcs.anl.gov/petsc/petsc-current/docs/manualpages/KSP/KSPType.html

See all preconditioner methods available:

https://www.mcs.anl.gov/petsc/petsc-current/docs/manualpages/PC/PCType.html

...and modify the `transformateur.champs` file to see what you get!

You can contact us if you have requests about MEF++:

mefpp@giref.ulaval.ca

Hope you enjoyed!
Thanks!