

# HACKATHON 2016

REAL FLUID TEAM  
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8TH OF JULY, 2016

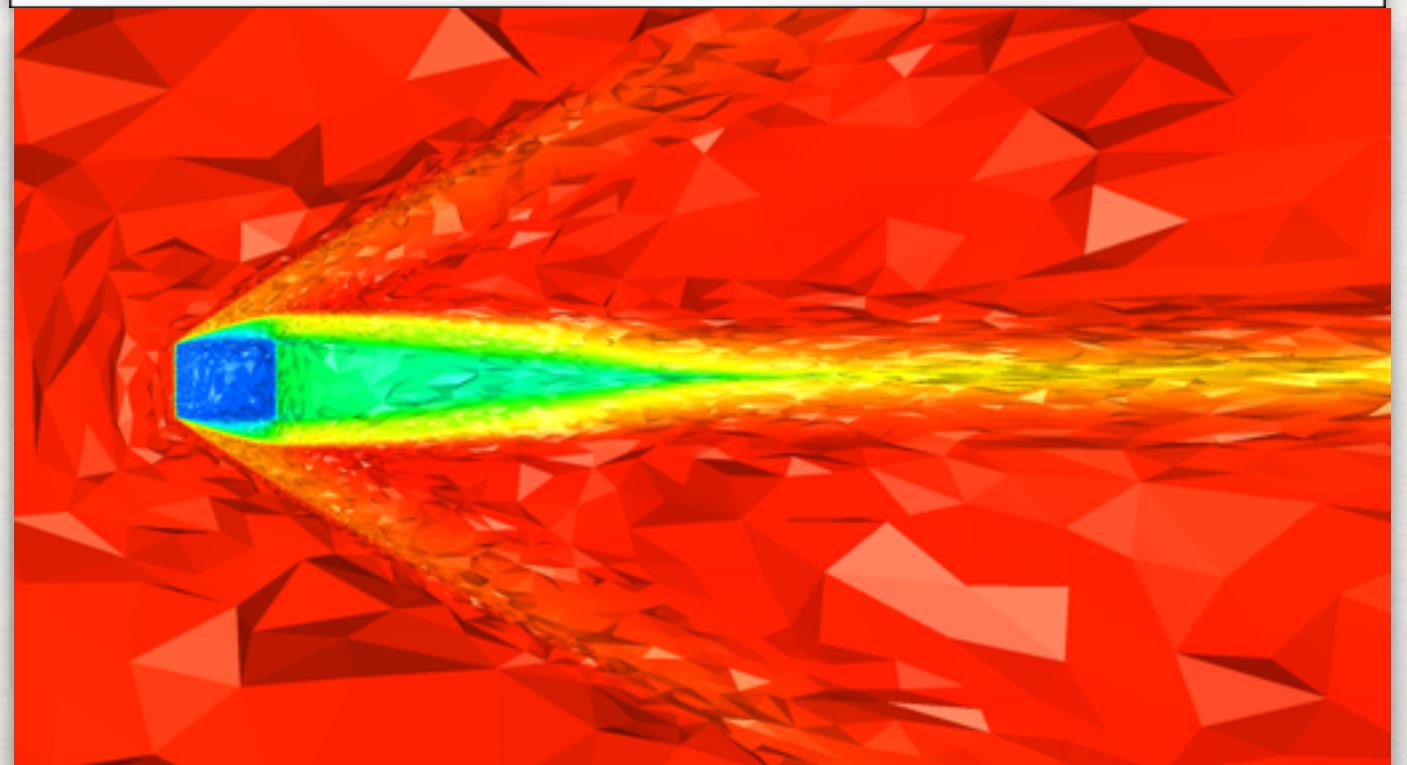
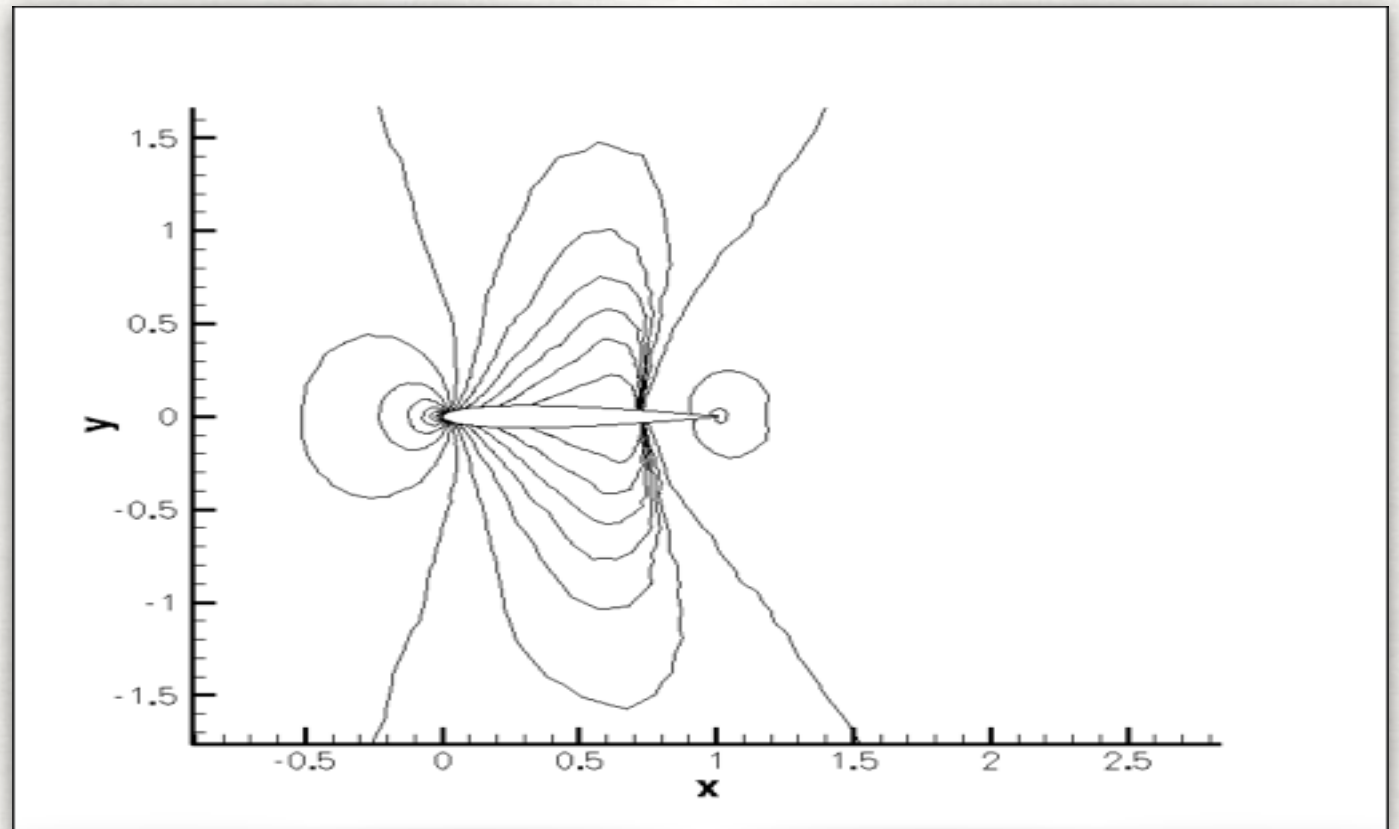
# REALFLUID APPLICATION

Computational Fluid Dynamics (CFD) code:

- Aerodynamics (plane, ice shedding, ...)
- Aerospatial (atmospheric entry, ..)

1) Subsonic flow -Pressure isolines around 2D naca0012 airfoil

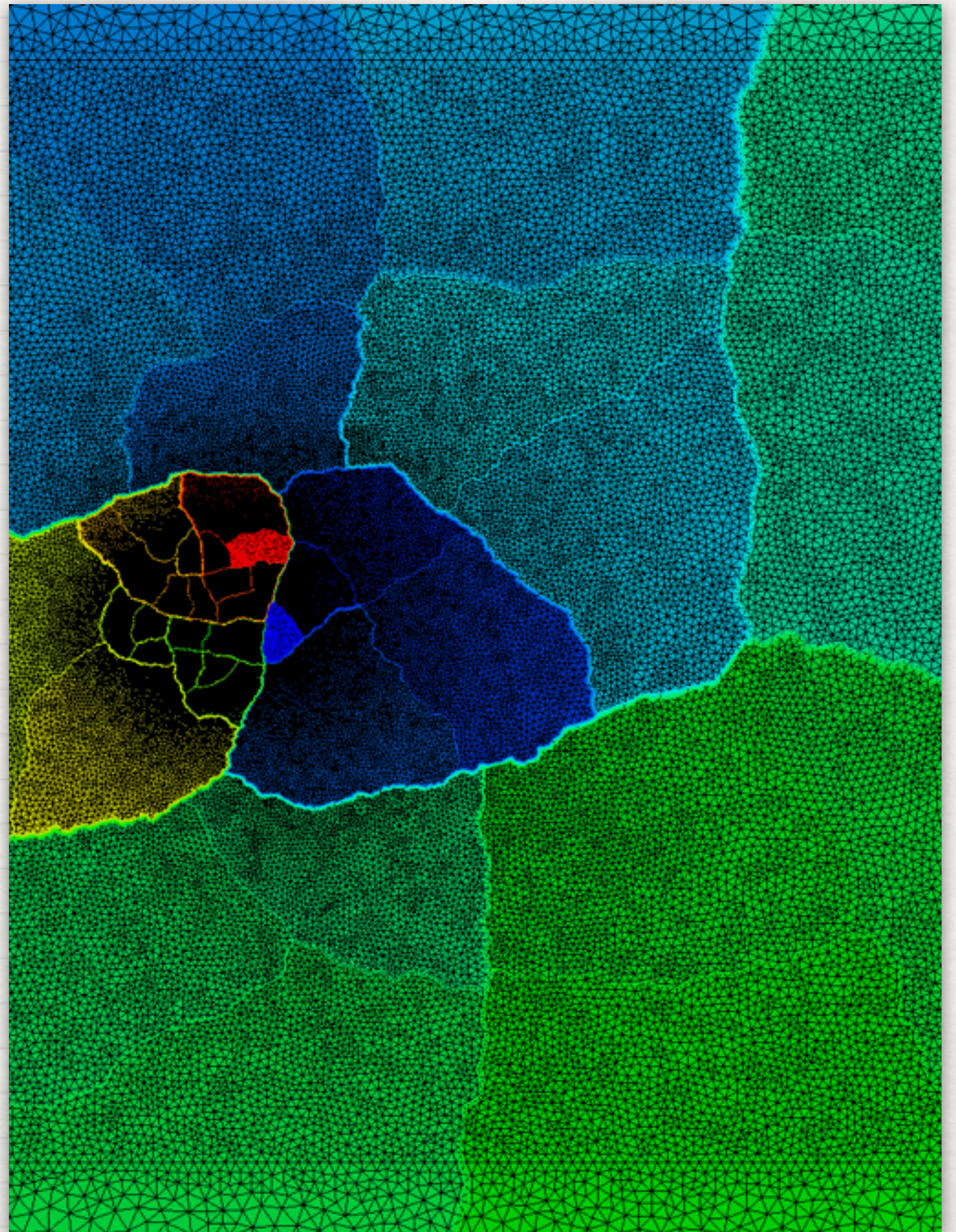
2) Supersonic Flow - Velocity around triangular shape





# NEED OF PARALLELISM

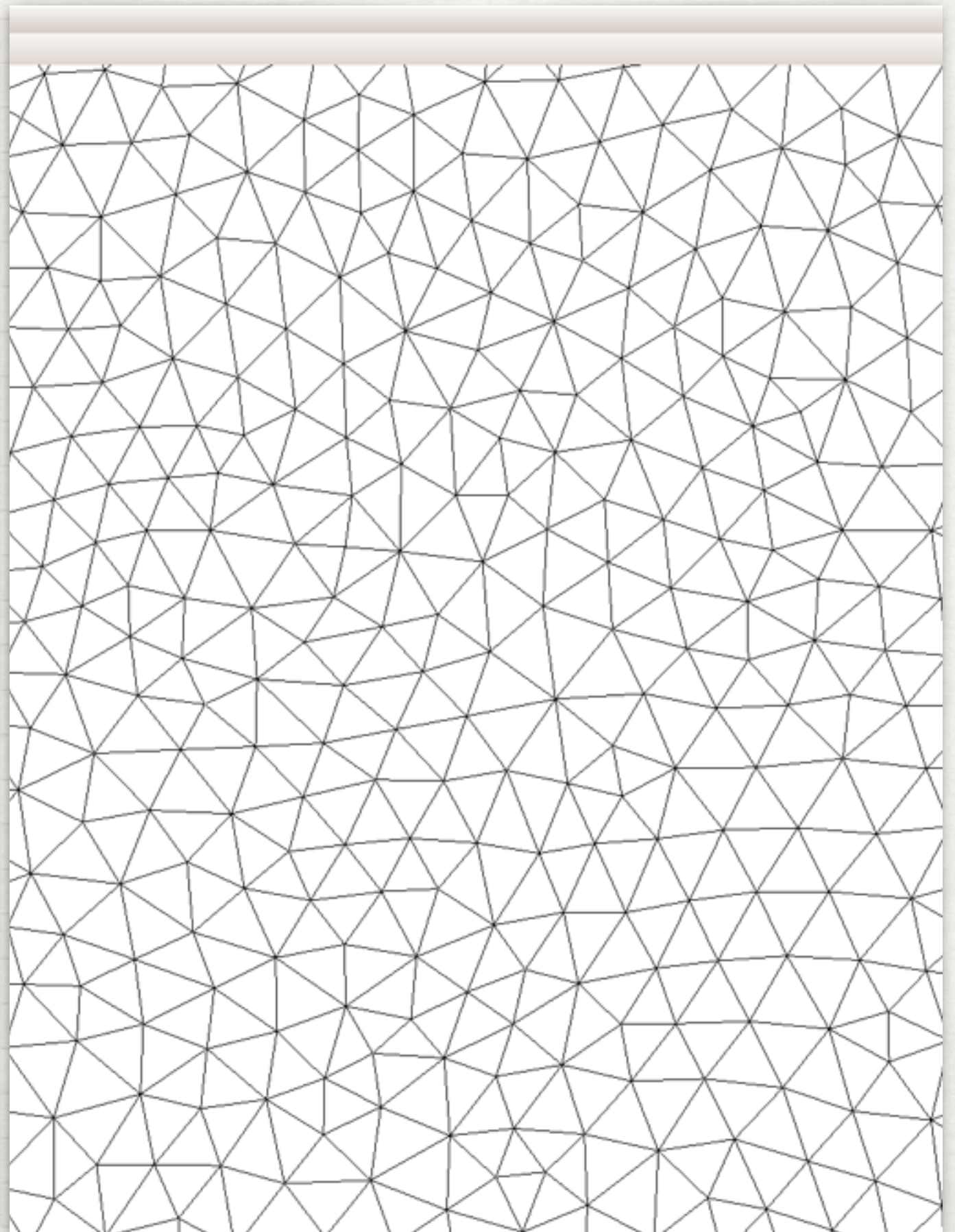
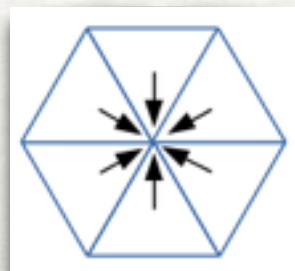
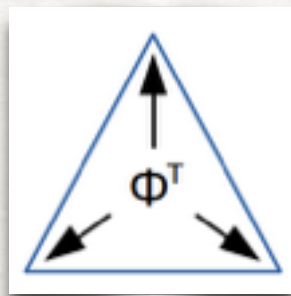
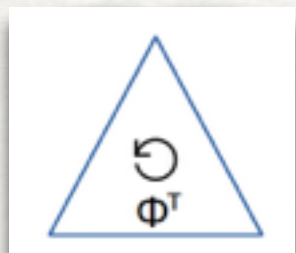
- MESH FOR SPATIAL DISCRETISATION.
- NEED OF PRECISION  $\Rightarrow$  INCREASE OF NODES NUMBER  $\Rightarrow$  INCREASE OF THE COMPUTATIONAL COST.
- SEPARATION ON THE DOMAIN INTO SUBDOMAINS.
- EACH PROCESSOR HANDLE ONE SUBDOMAIN.





# AIM OF THE WEEK

- BIG ARRAYS FOR NODALS VALUES
- LOOP ON THE ELEMENTS CAN BE DISTRIBUTED ON THE GPU IN ORDER TO COMPUTE THE TOTAL RESIDUAL AND DISTRIBUTE IT TO NODES
- REDUCTION OF THE "CONTRIBUTION" OF THE VALUES TO THE NODES





## Sequential Profiling with CRAY

## What do we need to parallelize

hck14@daint102:~/test\_cases/Sphere

Loop Incl Time%	Loop Incl Time	Time (Loop Adj.)	Loop Hit	Loop Trips Avg	Loop Trips Min	Loop Trips Max	Function=/.LOOP[.]
41.5%	88.219466	0.027379	1	1.0	1	1	boucle_en_temps\$boucleentemps_.LOOP.1.li.173
39.1%	83.051305	1.842315	1	606,125.0	606,125	606,125	imp_rd_fuq\$space_integration_.LOOP.1.li.173
32.1%	68.234192	1.096609	1	606,125.0	606,125	606,125	init_elements\$elements_driver_.LOOP.01.li.58
29.2%	62.087931	62.087931	1	634,353.0	634,353	634,353	readmeshgmsh2\$readmesh_.LOOP.3.li.2386
18.5%	39.263347	0.070799	606,125	4.0	4	4	total_residual_imp\$space_integration_.LOOP.4.li.894
18.4%	39.192549	0.480041	2,424,500	4.0	4	4	total_residual_imp\$space_integration_.LOOP.5.li.899
18.2%	38.712508	0.343941	9,698,000	3.0	3	3	total_residual_imp\$space_integration_.LOOP.6.li.908
18.1%	38.368567	20.807297	7,273,500	6.0	6	6	total_residual_imp\$space_integration_.LOOP.7.li.915
11.8%	25.162856	2.021124	606,125	4.0	4	4	init_faces_tet_pl\$tetrahedron_class_.LOOP.1.li.730
9.3%	19.770975	3.739336	2,452,728	6.0	6	6	face_quadrature_sub\$triangle_f_class_.LOOP.1.li.256
9.1%	19.315840	0.750315	606,125	4.0	4	4	volume_quadrature\$tetrahedron_class_.LOOP.1.li.237
7.8%	16.641562	8.936853	2,424,500	4.0	4	4	volume_quadrature\$tetrahedron_class_.LOOP.2.li.239
7.8%	16.595227	0.153702	606,125	4.0	4	4	total_residual_imp\$space_integration_.LOOP.1.li.769
7.7%	16.441525	6.221579	2,424,500	6.0	6	6	total_residual_imp\$space_integration_.LOOP.2.li.778
6.9%	14.677451	0.043560	606,125	4.0	4	4	nodal_gradients\$tetrahedron_class_.LOOP.1.li.295
6.9%	14.633891	7.326016	2,424,500	4.0	4	4	nodal_gradients\$tetrahedron_class_.LOOP.2.li.297
6.9%	14.583980	0.000000	606,125	4.0	4	4	lf_scheme_imp_diag\$scheme_lf_.LOOP.06.li.188
4.7%	9.970994	0.000000	2,424,500	4.0	4	4	lf_scheme_imp_diag\$scheme_lf_.LOOP.10.li.249
4.0%	8.401150	8.401150	9,698,000	4.0	4	4	lf_scheme_imp_diag\$scheme_lf_.LOOP.12.li.327
2.8%	5.856769	5.856769	24,245,000	4.0	4	4	compute_jacobian\$tetrahedron_class_.LOOP.1.li.635
2.6%	5.424406	5.424406	14,716,368	3.0	3	3	face_quadrature_sub\$triangle_f_class_.LOOP.2.li.258
2.5%	5.271523	5.271523	43,641,000	3.0	3	3	total_residual_imp\$space_integration_.LOOP.8.li.924
2.1%	4.556335	0.043400	606,125	4.0	4	4	lf_scheme_imp_diag\$scheme_lf_.LOOP.18.li.447
2.1%	4.512935	1.649834	2,424,500	4.0	4	4	lf_scheme_imp_diag\$scheme_lf_.LOOP.19.li.449
1.9%	4.022356	4.022356	38,792,000	3.0	3	3	lf_scheme_imp_diag\$scheme_lf_.LOOP.13.li.330
1.9%	3.966051	0.014706	606,125	1.0	1	1	recovery_procedure\$tetrahedron_class_.LOOP.1.li.342
1.9%	3.951345	2.081395	606,125	4.0	4	4	recovery_procedure\$tetrahedron_class_.LOOP.2.li.344
1.8%	3.871997	0.022977	1	20.0	20	20	blu_sgs\$lusgs_method_.LOOP.2.li.264
1.4%	2.976054	1.072215	24,245,000	3.0	3	3	compute_jacobian\$tetrahedron_class_.LOOP.2.li.640
1.2%	2.631432	0.541108	1	2,424,500.0	2,424,500	2,424,500	geomface3d\$geomgraph_.LOOP.5.li.4141
1.2%	2.601716	2.601716	2	606,125.0	606,125	606,125	reprise_outbin\$reprise_.LOOP.1.li.404
1.0%	2.211025	2.211025	14,801,052	3.0	3	3	normal\$triangle_f_class_.LOOP.1.li.434

Afficher les lignes 165-200/220 89%



# EVOLUTION & PROBLEMS

- WE STARTED WITH ACC IMPLEMENTATION  $\sim O(10)$  SLOW
  - DATA MOVEMENT, LITTLE PARALLELISM ON GANG LEVEL
- MOVING UP THE PARALLELISM
- AVOID DATA RACES - CREATE HUGE ARRAY
- ACCELERATED FIRST LOOP WITH PARALLEL LOOP

!\$ACC PARALLEL LOOP

```
DO K = 1, N_DOFS
  STAB_LEFT_K = 0.DO
  DO ID = 1, N_DIM
    STAB_LEFT_K = STAB_LEFT_K + &
      AA_Q(:, :, ID) * D_PHI_Q(ID, K, IQ)
  ENDDO
```

```
JAC_STAB_LW(:, :, I, K) = JAC_STAB_LW(:, :, I, K) + &
  W(IQ) * MATMUL( STAB_LEFT_I, &
    TAU * STAB_LEFT_K )
```

```
ENDDO ! # DOFS -> K
```

!\$ACC END PARALLEL LOOP

Fortran intrinsic MATMUL not  
implemented for GPU  
Manual implementation:  
acc routine  
Think about parallelism for  
routine construct



- Applied also for matrix-  
vector multiplication

```
SUBROUTINE MatMult(A,B,C)  
!$acc routine vector
```

```
!Definitions omitted here
```

```
#ifdef _OPENACC
```

```
!$acc loop
```

```
DO i=1,s
```

```
  DO j=1,r
```

```
    DO l=1,t
```

```
      C(i,j)=C(i,j)+A(i,l)*B(l,j)
```

```
    END DO
```

```
  END DO
```

```
END DO
```

```
!$acc end loop
```

```
#else
```

```
C=MATMUL(A,B)
```

```
#endif
```

```
END SUBROUTINE MatMult
```



- Linker error with PGI (cudaMalloc, cudaFree)
- Scalar-matrix multiplication in routine arguments

```
call MatMult(Stab_left_i, Tau *  
Stab_left_k, Matmultres)
```

- Workaround: Own temporary array

```
TauStab_left_k = Tau * Stab_left_k  
call MatMult(Stab_left_i,  
TauStab_left_k, Matmultres)
```

- Consistent usage of Pointers:  
CONTIGUOUS

```
REAL, DIMENSION(:, :), POINTER ::  
VAR
```

```
REAL, DIMENSION(:, :), POINTER, CONTIGUOUS ::  
VAR
```



## ERROR for PGI compiler:

```
Unhandled builtin: 601
  (pgf90_mzero8)
PGF90-F-0000-Internal compiler
error. Unhandled builtin function. 0
(/users/hck12/Projects/RealFluid/
  trunk/
  MODELS/OrdreEleve/
  Contrib_Eul.f90: 167)
```

FIXED: -Mnoidiom

## Copying the data:

- we tried firstly : !\$acc kernels

**ERROR:** "Unsupported OpenACC  
construct Deep Copy"

- It's a bug in the CRAY compiler



```
935, Loop is parallelizable
pgnvd-Fatal-/scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm TERMINATED by signal 9
Arguments to /scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm
/scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm -opt=0 -g -arch=compute_35 -ftz=1 -prec-div=1 -prec-
sqrt=1 -fma=1 /tmp/pgaccv4Wc-zIG8nxb.gpu /scratch/daint/hck39/pgi/linux86-64/2016/cuda/7.0/nvvm/
libdevice/libdevice.compute_30.10.bc /scratch/daint/hck39/pgi/linux86-64/16.7/lib/pgi_cuda_runtime.ll /
scratch/daint/hck39/pgi/linux86-64/16.7/lib/pgi_cublas_runtime.ll /tmp/pgaccL4WcV4IWmQyD.ptx
PGF90-S-0155-Compiler failed to translate accelerator region (see -Minfo messages): Device compiler
exited with error status code (/users/hck12/Projects/RealFluid/trunk/MODELS/OrdreEleve/
Space_integration.f90: 1)
 0 inform, 0 warnings, 1 severes, 0 fatal for
make[3]: *** [CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Space_integration.f90.o] Error 2
make[2]: *** [CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Space_integration.f90.o.provides] Error 2
make[1]: *** [CMakeFiles/FBx0Ea.dir/all] Error 2
make: *** [all] Error 2
```



```

935, Loop is parallelizable
pgnvd-Fatal-/scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm TERMINATED by signal 9
Arguments to /scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm
/scratch/daint/hck39/pgi/linux86-64/16.7/bin/pgnvvm -opt=0 -g -arch=compute_35 -ftz=1 -prec-div=1 -prec-sqrt=1 -
fma=1 /tmp/pgaccv4Wc-zIG8nxb.gpu /scratch/daint/hck39/pgi/linux86-64/2016/cuda/7.0/nvvm/libdevice/
libdevice.compute_30.10.bc /scratch/daint/hck39/pgi/linux86-64/16.7/lib/pgi_cuda_runtime.ll /scratch/daint/
hck39/pgi/linux86-64/16.7/lib/pgi_cublas_runtime.ll /tmp/pgaccL4WcV4IWmQyD.ptx
PGF90-S-0155-Compiler failed to translate accelerator region (see -Minfo messages): Device compiler exited with
error status code (/users/hck12/Projects/RealFluid/trunk/MODELS/OrdreEleve/Space_integration.f90: 1)
  0 inform,  0 warnings,  1 severes,  0 fatal for
make[3]: *** [CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Space_integration.f90.o] Error 2
make[2]: *** [CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Space_integration.f90.o.provides] Error 2
make[1]: *** [CMakeFiles/FBx0Ea.dir/all] Error 2
make: *** [all] Error 2

```

## We start again

```

PGF90-S-1000-Call in OpenACC region to procedure 'pgf90_copy_f90_argl' which has no acc routine information (/users/
hck12/FakeFluid/trunk/MODELS/OrdreEleve/Scheme_LF.f90: 476)

```

```

179, Accelerator restriction: call to 'pgf90_copy_f90_argl' with no acc routine information

```

```

179      Tau = theta*Tau_matrix_diag( N_verts, ele%Volume, ele%rd_n, Vp_b )

```

```

78      REAL(KIND=8), DIMENSION(:,,:), POINTER, CONTIGUOUS :: rd_n => NULL()

```

```

vlink error   : Prototype doesn't match for 'advection_interp_vp_' in 'CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/
Advection.f90.o', first defined in 'CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Advection.f90.o'
nvlink error   : Prototype doesn't match for 'advection_mean_state_vp_' in 'CMakeFiles/FBx0Ea.dir/MODELS/
OrdreEleve/Advection.f90.o', first defined in 'CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/Advection.f90.o'
nvlink error   : Undefined reference to 'cudaMalloc' in 'CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/
Space_integration.f90.o'
nvlink error   : Undefined reference to 'cudaFree' in 'CMakeFiles/FBx0Ea.dir/MODELS/OrdreEleve/
Space_integration.f90.o'

```



Linking Fortran executable /users/hck13/Code\_day5\_morning/RealFluidDay5v2.0/BIN/FBxOEa

nvlink error : Undefined reference to 'cudaMalloc' in 'CMakeFiles/FBxOEa.dir/MODELS/  
OrdreEleve/Space\_integration.f90.o'

nvlink error : Undefined reference to 'cudaFree' in 'CMakeFiles/FBxOEa.dir/MODELS/  
OrdreEleve/Space\_integration.f90.o'

Fixed: -lcudadevrt

Not enough memory:

```
malloc: cuMemMallocManaged returns error code 2
0: ALLOCATE: 32 bytes requested; not enough memory
srun: error: nid00008: task 0: Exited with exit code 127
srun: Terminating job step 244540.0
```