Postprocessing of 2D FEATFLOW Data with the Particle Tracing Tool GMVPT (Version 1.0)

J.F.Acker, S.Turek
Institut für Angewandte Mathematik, Universität Heidelberg
Im Neuenheimer Feld 294, 69120 Heidelberg, Germany
Email: featflow@gaia.iwr.uni-heidelberg.de
Homepage: http://www.iwr.uni-heidelberg.de/~featflow

22nd June 1999

Contents

1 How to start ?

1.1 Installation

First you have to copy the source file gmvpt.c (which is downloadable from our homepage) into the same directory where e.g. the FEATFLOW simulation tools pp2d or cc2d are located. Then you have to compile the source with your preferred C-compiler, e.g. gcc:

gcc -O3 -o gmvpt gmvpt.c

If you use bouss, that means the modified version of pp2d including temperature, you have to do the following variant:

gcc -O3 -DBOUSS -o gmvpt gmvpt.c

If you have modified the output-routines in FEATFLOW or if you want to apply GMVPT for other GMV data not created by FEATFLOW, make the corresponding modifications of gmvpt.c.

1.2 Directory structure

You need the following directories and files to successfully run GMVPT:

1. A coarse mesh #gmv/coarse.gmv, e.g. generated by invoking trigen2d (see [1]). This is needed to visualize the domain.
2. Data files #gmv/u.*.gmv, e.g. generated by bouss. GMVPT scans automatically for its input files, starting the search at #gmv/u.1.gmv.
3. A configuration file #data/gmvpt.dat.

1.3 Syntax of the configuration file

The configuration file is only a bunch of integer and floation points values. Linebreaks and blanks between those numbers are ignored. It's up to you to make it readable by inserting some linebreaks and blanks.
Unsigned integer values are preceeded by '#'. Everything else is a **floating point** value.

> <#Number of time steps> <Duration of a single time step for particle tracing> <#Read next input file after this number of time steps> <#Write next tracer file after this number of time steps>
>
> <#Number of Blocks>

Each mxn block of (starting) tracers with lower left corner (x1,y1) and upper right corner (x2,y2) is given by:

> <x1> <y1> <x2> <y2> <#n> <#m> <#Insert this block after this number of time steps (frequency)> <#Subtract this offset to the number of time steps (phase change)> <#First time step> <#Last time step> <Value of data field 'Farbe'> <Remove particles after this time (lifetime)>

1.4 A short examplary configuration file

```
1000 0.05 2 2
2
0.0 0.0 0.1 0.1 10 10 4 0 0 999 0.0 25.0
0.0 0.0 0.1 0.1 10 10 4 1 0 999 1.0 25.0
```

This sample file makes 1000 micro time steps with duration 0.05. Every second time step it reads a new input file and writes a new tracer file (be sure to have enough input files!). This implicitly requires that the time step in the simulation process to output the data was 0.1. There are two blocks located at (0.0,0.0)-(0.1,0.1) with a 10x10 grid of tracers. Each tracer exists for 25 seconds. Both blocks are inserted each fourth time step, but the second has a phase change. The effect is, that tracers with color 0.0 are inserted at time steps 0,4,8,12,... and tracers with color 1.0 are inserted at time steps 1,5,9,13,... (if (i-1) mod 4 = 0 is true for time step i). To adjoin real colors to these values you have to modify the data limits of tracer field Farbe and to adjust the colormap to your needs. It will generate output files named t.1.gmv, t.2.gmv, ..., t.500.gmv.

2 Visualisation of Particles using GMV

2.1 Preparations

After starting GMV (see also [5]), open the cells menu at Display/Cells. Then deactivate Faces and activate Edges. Adjust also magnification, line color and line width to get a proper display of the underlying coarse mesh.

Figure 1: Tracers Menu

2.2 The Tracers Menu

Open the tracers menu at Display/Tracers. There you can activate different representations of tracers. Normally choose Regular Points. You can also chose between different data fields which determinate, together with the color map and actual data limits, the color of each tracer/particle (see Fig. 1). Open the specific data limits menu at Controls-1/Data Limits/Tracers. There you can explicitly specify data limits for each data field. If you activate Auto Reset or Auto Reset All, for each single input file and for selected or all data fields, GMV calculates actual data limits. Turn off the color bar if you want to make an animation, since GMV would normally change in every frame such that it becomes unreadable (see Fig. 2).

2.3 Generating MPEG videos with GMV

First load one of your generated t.*.gmv files. Adjust GMV to get the desired visualisation of your tracers and create an attribute file test.attr with Files/Put Attributes. Then further steps depend on which tools you want to use (e.g. image size 640x480, number of frames 250, name of MPEG will be test.mpeg):

- MKYUV/MKMPEG (see [2]):

  1. Replace every 'u.' by 't.' in the file mkyuv.c and recompile mkyuv.
  2. Invoke MKYUV with mkyuv 640 480 test.attr test 1 250.
  3. Invoke MKMPEG with mkmpeg 640 480 test 250.

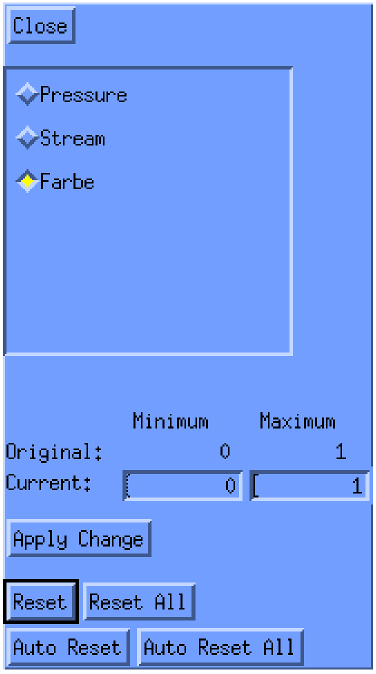

Figure 2: Set Tracers Limits Menu

- GMVMPEG (see [4]):

  Invoke GMVMPEG with gmvmpeg -a test.attr -x 640 -y 480 -fls 1,250,1 -o test.
  If you have installed the virtual framebuffer Xvfb, you can add the option '-I' to avoid annoying popups by GMV.

3 Examples

3.1 Flow around a Cylinder

The problem here is to visualize the vortex shedding behind a cylinder. We continuously insert a rectangular area of tracers with a constant frequency to simulate a constant stream of particles. Between each frame we make ten interpolating time steps (if each input file has time difference 0.025, you have to ensure that time step is 0.025/10=0.0025, to be synchronous with the simulation). An examplary configuration file looks like the following (see Fig. 3 for its output).

```
2500 0.0025 10 10
1
0.0 0.175 0.1 0.225 10 5 27 0 0 2499 0.0 2.5
```

3.2 Leapfrogging of Smoke Rings ('Puff-Puff' Problem)

Here the problem is to visualize two smoke rings chasing each other. It's nearly impossible to visualize this flow configuration without particle tracing! We insert a squared 100x100 block of 10,000 particles located at (4.3,4.4)-(4.5,4.6) at times 0.0 and 120*0.03333333334=4.0 with different colors (0.0 represents blue, 1.0 represents red in the default color map, if we use a value range of 0.0-1.0 for data field 'Farbe'). Each input file corresponds to a time step of 0.1. Thus we make three interpolating time steps between the input files and due to the 500 input files, we

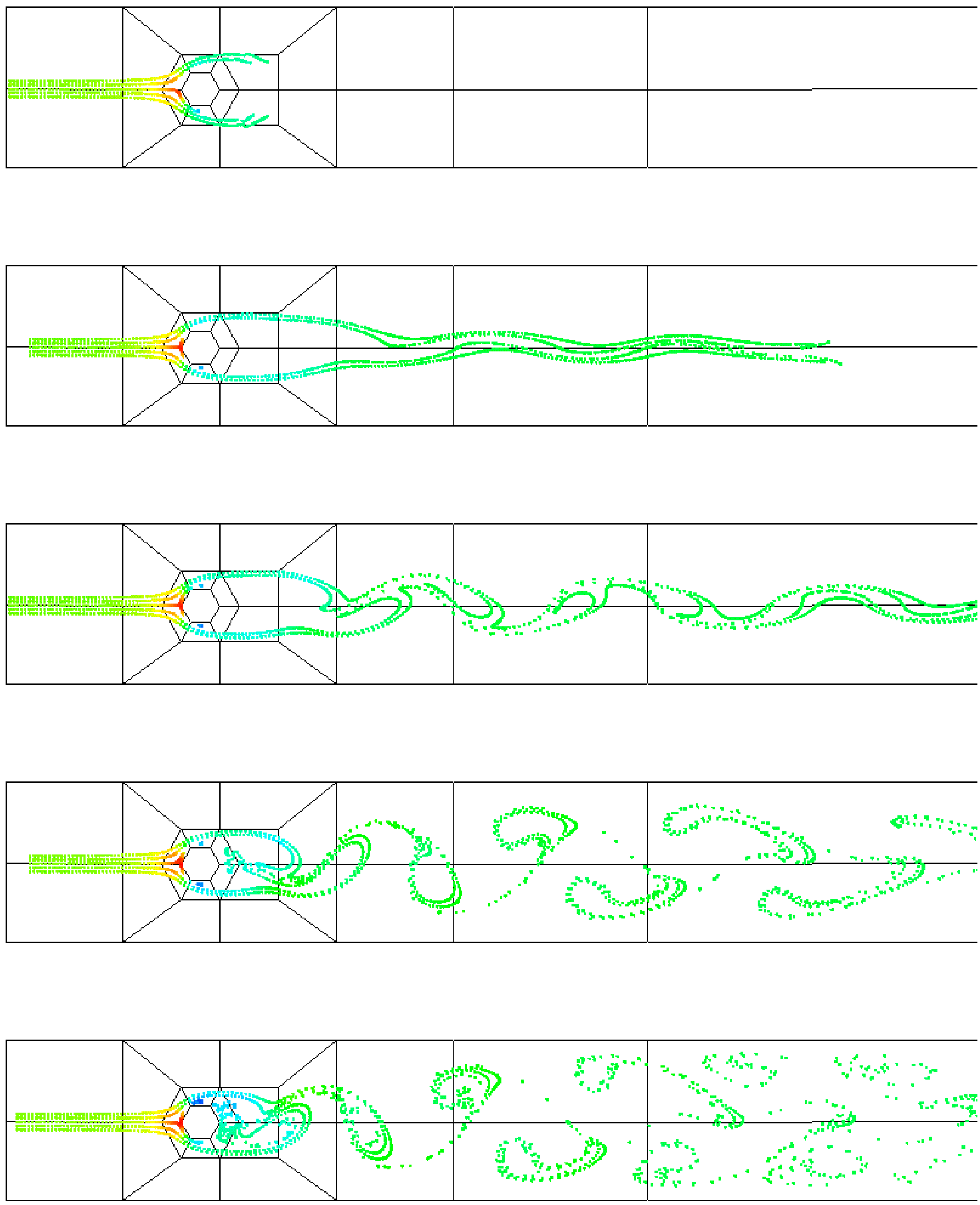

Figure 3: Vortex shedding behind a cylinder visualized by a particle stream

have to use a time step of about 0.1/3=0.033333... and we make 500*3=1500 time steps. An examplary configuration file, is shown below in this text (see Fig. 4 for its output).

```
1500 0.03333333334 3 3
2
4.3 4.4 4.5 4.6 100 100 1 0 0 0 0.0 50.1
4.3 4.4 4.5 4.6 100 100 1 0 120 120 1.0 50.1
```

4 Outlook

GMVPT 1.0 is only the very first **complete** version with a rich variety of configurations for particle tracing as postprocessing tool. At the moment, the process of 'finding particles in the mesh' is not yet optimally implemented such that the CPU time for many particles (>10.000) may be still very large.
However, due to its modularity, this part of the code will soon be replaced by a hierarchical searching tool with optimal complexity and run-time behaviour. Additionally, the following improvements for the next version are planned:

1. Improved interpolation (for different FEM spaces) and search algorithms.
2. Description of the domain without any mesh.
3. Adaptive time steps.
4. **The 3D variant!**

References

[1] Finite element software for the incompressible Navier-Stokes equations: User Manual. Release 1.1, 1998 (see also: *http://www.iwr.uni-heidelberg.de/˜featflow*)

[2] Working with GMV under FEATFLOW, J.F.Acker,1998 (see also: *http://www.iwr.uni-heidelberg.de/˜featflow* for the english version)

[3] 3D Presentation of FEATFLOW Data with GMV, J.F.Acker, S.Turek, 1999 (see also: *http://www.iwr.uni-heidelberg.de/˜featflow*)

[4] Batch-oriented MPEG generation with GMV in background mode: S.H.M. Buijssen, S.Turek, 1999 (see also: *http://www.iwr.uni-heidelberg.de/˜featflow* for downloading)

[5] GMV (General Mesh Viewer) user manual. Release 1.8, 1999 (see also: *http://www-xdiv.lanl.gov/XCM/gmv/GMVHome.html*)

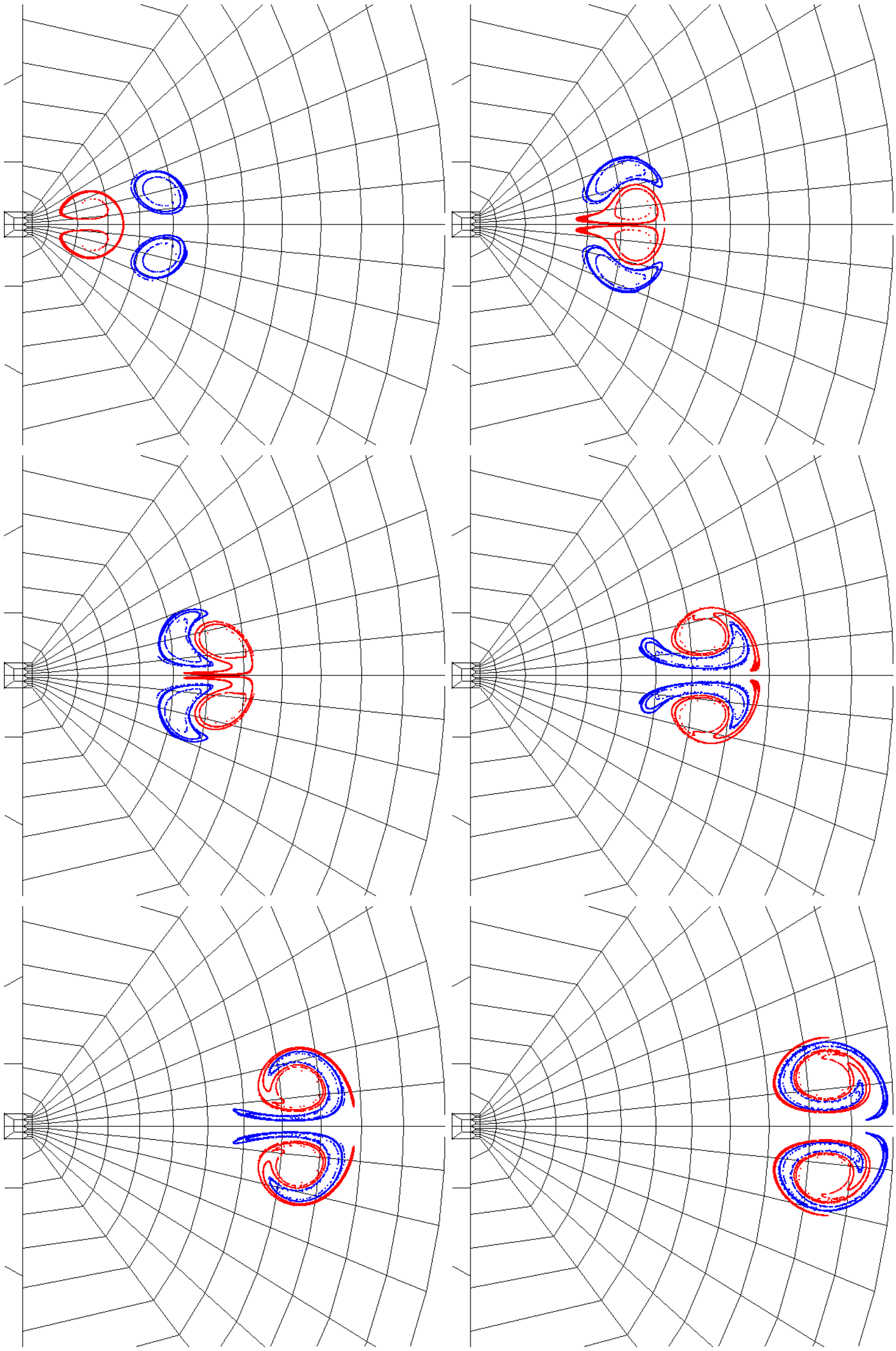

Figure 4: Two smoke rings chasing each other