PIVlab - Time-Resolved Digital Particle Image Velocimetry Tool for MATLAB

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Preface

PIVlab is an open-source particle image velocimetry (PIV) software that does not only calculate the velocity distribution within image pairs, but can also be used to derive, display and export multiple parameters of the flow pattern. A user-friendly graphical user interface (GUI) makes PIV analyses and data post-processing fast and efficient.

General remarks

A "*frame*" is defined as a pair of images including any derived parameters. Single analyses consist of one single frame (one image pair + results); a time-resolved analysis consists of multiple frames (several image pairs + results).

A "*session*" is defined as a collection of single or multiple frames including any derived parameters and all the settings of the GUI. Sessions can be saved and reloaded in PIVlab.

When creating masks, manually rejecting vectors, selecting areas/ poly-lines etc., the left mouse button performs the desired task, whereas the right mouse button ends this task.

The GUI is menu-based; selecting a menu item will change the panel that is displayed on the right hand side. When doing PIV analyses, the workflow should start at the left side of the menu, and continue to the right side.

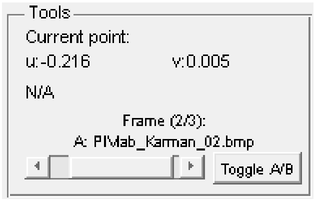
All files of the PIVlab package should be extracted to a folder in your MATLAB work directory. The folder should be added to the MATLAB search paths. PIVlab is started by entering "PIVlab_GUI" in the command window. When running PIVlab, your current directory should always be the folder where PIVlab_GUI.m is stored. You can also create a shortcut for PIVlab by adapting the following command:

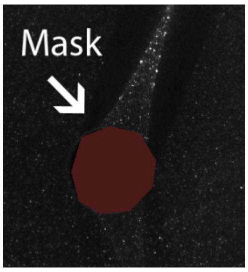
```
"C:\Program Files\MATLAB71\bin\win32\MATLAB.exe" -nosplash -minimize -r PIVlab_GUI
```

Example: Analyzing a series of images

This example will show you how to process a series of image pairs. Some of the possibilities of PIVlab will be mentioned.

First, load some images by selecting `File → New session`. Click `load images`. Select the images PIVlab_Karman_01.bmp till PIVlab_Karman_04.bmp. Select `sequencing style 1-2, 2-3, 3-4, …` and click `add`, then `done`. The image list on the right side displays the images that you selected. The letters A & B denote the first and the second image of one image pair. In the lower right corner, you will find a slider to navigate through all frames (image pairs), and a button to toggle between the individual images within one frame.

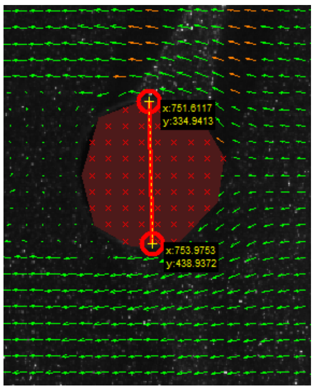




Continue to `Analyses settings → Exclusions (ROI, Mask)`. If you want to analyze the whole image, you don't need to set a ROI. But in this particular image, a mask should be applied to exclude the dark object (a cylindrical rod) from the analyses. `Click draw mask(s) for current image` and use the left mouse button to create a circular mask. Because the cylindrical rod doesn't move from one frame to the other, you can apply this mask to all frames by clicking `apply current mask(s) to all frames`. You can always draw more than one mask if necessary.

Proceed to `Analyses settings → PIV settings` to select the interrogation area and step width for the PIV analysis (recommended: 24px interrogation area, 12px step). Now, everything is set up for the PIV analyses. Navigate to `Analysis → Analyze!` and click `analyze all frames`. Some erroneous vectors will show up due to poorly illuminated regions in the image. They can be removed by selecting `Post processing -> vector validation`. You should select some velocity limits, set the standard deviation filter to 8*stdev and then click `Apply to all frames`. By default, a standard deviation filter is active and filtered vectors are interpolated. These options can also be disabled. Use the slider at the bottom right to see if all frames are correctly validated.

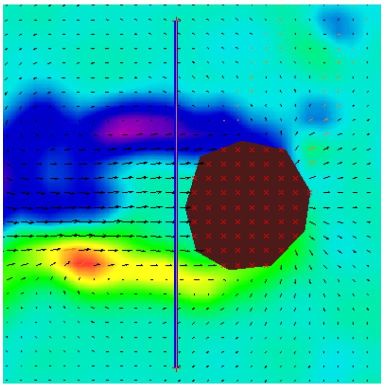
Click onto some vectors to display the local velocity at the bottom right. Until now, units are "pixels per image-pair". This can be changed by navigating to `Calibration → Calibrate using current or external image`. The calibration can be done using an external calibration image, or by using the currently displayed image. Click `select reference distance` and select the upper and lower edge of the cylinder. You can now enter the real diameter of the cylinder (30mm) and the time step (frame rate was 400Hz = 2.5 ms). The precision of this kind of calibration is pretty low, so external calibration images should be used if possible. Always use a point and not a comma as decimal sign!



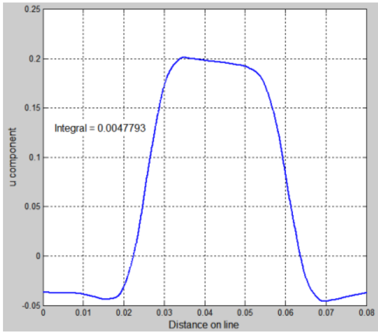
If you again click on some vectors, the velocity will be displayed in real units (m/s). The flow velocity in this experiment was around 0.2 m/s.

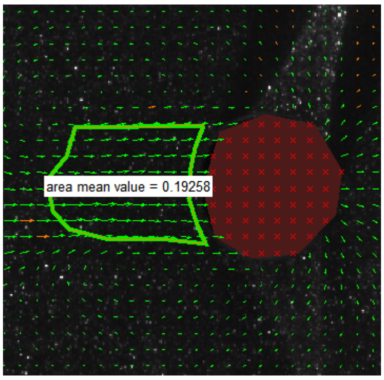
To display the vorticity in the flow, select `Plot → derive parameters/ modify data`. Select `vorticity` in the upper pop-up menu. Check `smooth data` and drag the slider a bit to the right. You can subtract the mean u velocity by clicking `mean u` (or enter any other velocity in the text box. Use the button `Apply to all frames` to apply all changes.

Scaling of vectors can be modified when selecting `Plot → modify plot appearance`. Scaling can also be set to `auto`.



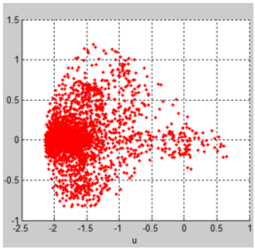
To have a look at the u-velocity profile behind the cylinder, go to `Extractions → parameters from poly-line`, select `u component` from the pop-up menu and click `Draw!` to draw a vertical line behind the cylinder. Clicking `Plot data` results in a new window that displays the u velocity along that line and the integral of the velocity. You can also draw circles around vortices and plot the tangential velocity. The integral of the tangential velocity along a loop enclosing a vortex, is equal to the circulation of that vortex.

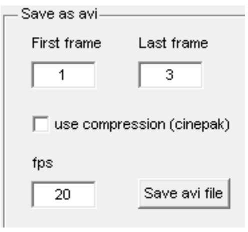




Parameters from user-selected areas can also be derived. Click `Extractions → parameters from area`, select `velocity magnitude` and click `Area mean value`. When drawing an area behind the cylinder, you can derive the average velocity magnitude behind the cylinder.

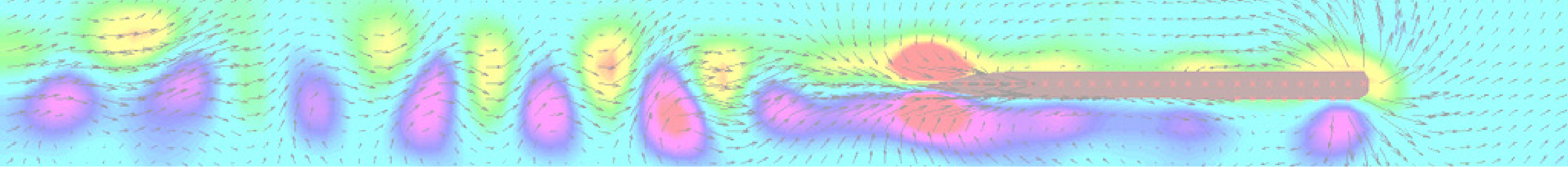
If you navigate to `Statistics → Statistics`, you can also display a scatter plot of u and v velocities by clicking `scatter plot u & v`.





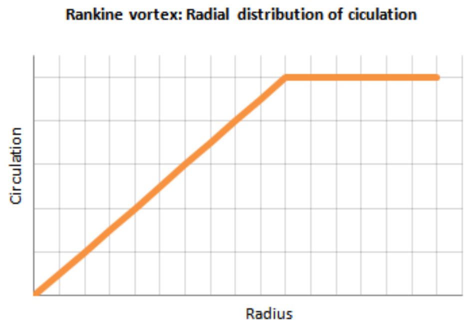
Data can be exported to MATLAB workspace (`File → save → all results to MATLAB workspace`), as MAT-file (`→ MAT-file`) and as ASCII-file (`→ ASCII x,y,u,v,vort`). Options can be chosen too. Movie files (.avi) can be created by selecting `File → save → movie file from frames`.

If you often do analyses with similar settings, you can save your preferred PIVlab settings by selecting `File → save → current PIVlab settings`. If you decide to save the current session, please notice that the source image files are not included in the MAT file! Only the file paths of the images are stored.



Calculating the circulation of a vortex

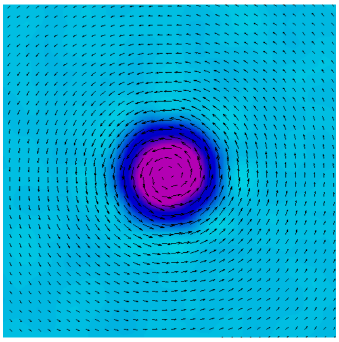
PIVlab 1.1 features the possibility to calculate the circulation of a vortex by integrating tangential velocity of a path around the vortex. Choosing the optimal path is often problematic. For a Rankine vortex, the circulation increases with radius inside the rotational core, and stays constant outside the vortex core. The optimal path for the integration of tangential velocity is hence the boundary of the vortex core.



Circulation vs. radius of a Rankine vortex

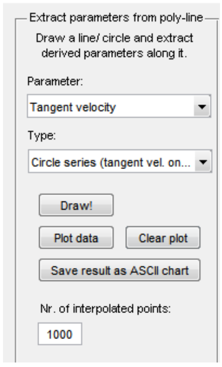
In real vortices, the vortex core is sometimes hard to identify (due to dissipation caused by viscosity and the limited resolution of PIV). Therefore PIVlab can calculate the circulation for a series of paths with increasing diameter, the maximal circulation will be found close to the boundary of the vortex core.

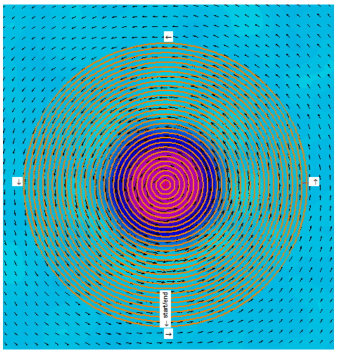
To calculate the circulation of a vortex, follow these steps:



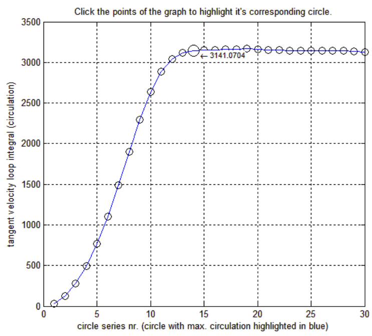
Analyze your image pair, and let PIVlab display vorticity. Go to `Extractions` → `parameters from poly-line`, and select `tangent velocity` as parameter and `circle series` as type.

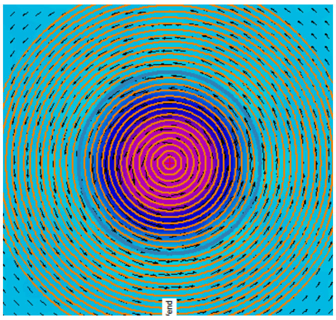
Click `Draw`, then click into the centre of the vortex, and then again somewhere outside of the potential vortex core.





PIVlab will draw a series of 30 circles with increasing diameter. Next, click `Plot data` to make PIVlab calculate the circulation of each circle. A new plot will appear with circle diameter on the x-axis and circulation on the y-axis.





Maximal circulation will be found at the boundary of the vortex core. PIVlab also highlights the circle with maximal circulation in blue.

You can also click on the points in the circulation plot to highlight the corresponding circle in the main window.

Success with your analyses…!