FlowVelo: An image-based tool to automatically measure flow velocities

This program tracks flow velocities using image or frame sequences. It includes measuring the camera position and orientation (camera pose), automatic extraction of the water area for feature searching, particle detection and filtering, particle tracking and filtering and scaling the tracks to get flow velocities. Furthermore, a function is included to automatically co-register frames in case of camera movements.

Source code:
https://github.com/AnetteEltner/FlowVeloTool

Requirements:
Python 2.7
Tkinter
scipy 1.2.1
scikit-learn 0.20.3
scikit-image 0.14.2
shapely
imageio 2.5.0
opencv 3.2.0
seaborn 0.9.0
matplotlib 2.2.2

Running FlowVelo on Windows

- Install Anaconda for Python 2.7
- You need to install opencv extra
    - Either open cmd and type (if conda not found add C:\Users\*YourUser*\Anaconda2\Scripts and C:\Users\*YourUser*\Anaconda to environment variable):
        - conda install -c conda-forge opencv=3.2.0
    - or open anaconda prompt and type
        - pip install opencv-python==2.3.0.6
- Unpack FlowVeloTool.zip and put all scripts including the tutorial folder into one folder
- Launch Spyder
- Open *GUI_FeatureDetectionTracking.py*

Running FlowVelo on Linux

- open Terminal and type:
    - python /*your_path*/GUI_FeatureDetectionTracking.py
- There might be an issue with the screen resolution, hindering the visibility of the entire window. If this is the case, please lower the screen resolution.

Input data:

- Interior geometry of the camera. Minimum information needed is focal length in mm, sensor size in mm and sensor resolution in pixels. There is an example file *interiorGeometry.txt* in the tutorial data and corresponding explanation of parameters in *interiorGeometry_explained.txt*.
- Image coordinates (id,x,y) of Ground Control Points (GCPs used to estimate camera pose in pixels, starting at the top left corner of the image. There is an example file *markersGCPimg.txt* in the tutorial data. Locations of GCPs in the image are illustrated in *locationGCPs_frame3.jpg*. This information is not necessary if the exterior camera geometry is provided directly.
- Object space coordinates (ID,X,Y,Z) of GCPs used to estimate camera pose. There is an example file *markersGCPobj.txt* in the tutorial data. If no GCPs are given it is possible to set the exterior camera geometry directly, if it is known.
- 3D point cloud (X,Y,Z) of area of interest to define search area. There is an example file *3DmodelPointCloud.txt* in the tutorial data. If no point cloud is given, it is also possible to import a file containing the image coordinates of the search mask.
- Water level
- Folder with the image/frame sequence

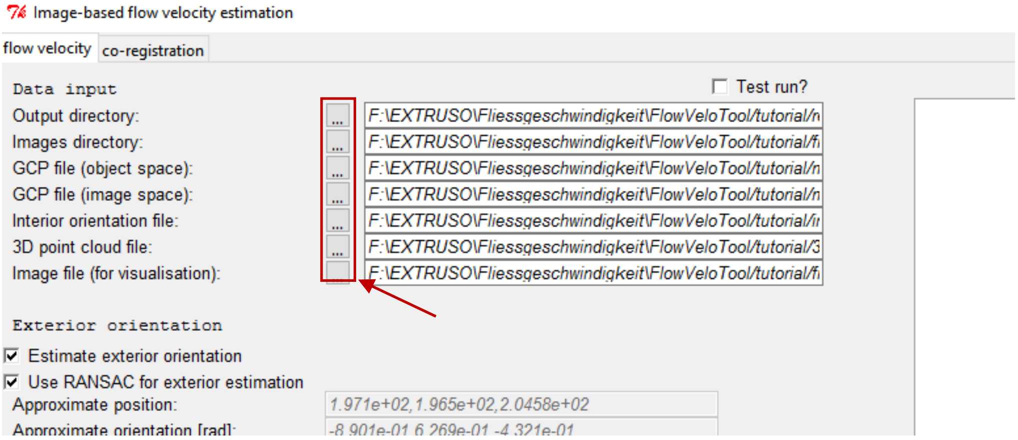
Tutorial data:

FlowVeloTool.zip available at
https://cloudstore.zih.tu-dresden.de/index.php/s/2XWTnzqCkoOJvkF

For questions please contact: Anette.Eltner@tu-dresden.de

<u>Short Guideline to estimate flow velocities:</u>

1. Set directories and files to input/output data:



Data input

□ Test run?

Output directory: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/n

Images directory: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/fi

GCP file (object space): F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/n

GCP file (image space): F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/n

Interior orientation file: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/ii

3D point cloud file: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/3

Image file (for visualisation): F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/fi

Exterior orientation

☑ Estimate exterior orientation

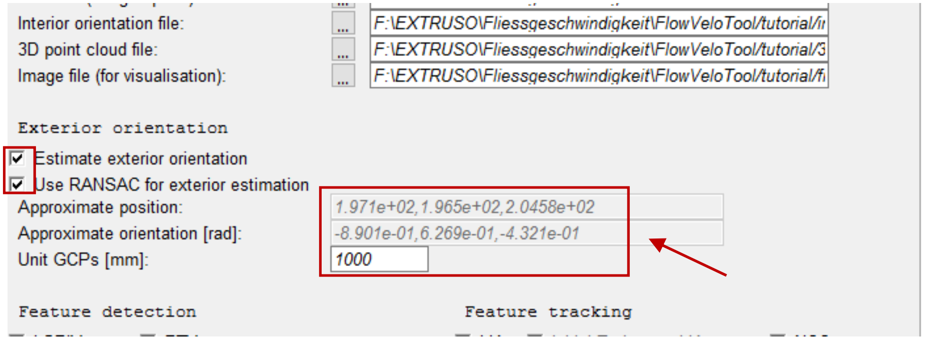
☑ Use RANSAC for exterior estimation

Approximate position: 1.971e+02,1.965e+02,2.0458e+02

Approximate orientation [rad]: -8.901e-01,6.269e-01,-4.321e-01

- "GCP file (object space)": ascii (txt-) file containing point id, X coordinate, Y coordinate, Z coordinate
- "GCP file (image space)": ascii (txt-) file containing point id, x image coordinate (in pixels), y image coordinate (in pixels)
- "Interior orientation file": ascii (txt-) file containing focal length, principle point, radial distortion parameters, tangential distortion parameters, affinity and shear parameters, sensor size and image resolution
- "3D point cloud file": ascii (txt-) file containing coordinate X, coordinate Y, coordinate Z
- "Image file (for visualisation)": Select image file (.img) in which results of feature detection and tracking will be displayed.

2. Set parameters for camera pose estimation:



Interior orientation file: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/ii

3D point cloud file: F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/3

Image file (for visualisation): F:\EXTRUSO\Fliessgeschwindigkeit\FlowVeloTool/tutorial/fi

Exterior orientation

☑ Estimate exterior orientation

☑ Use RANSAC for exterior estimation

Approximate position: 1.971e+02,1.965e+02,2.0458e+02

Approximate orientation [rad]: -8.901e-01,6.269e-01,-4.321e-01

Unit GCPs [mm]: 1000

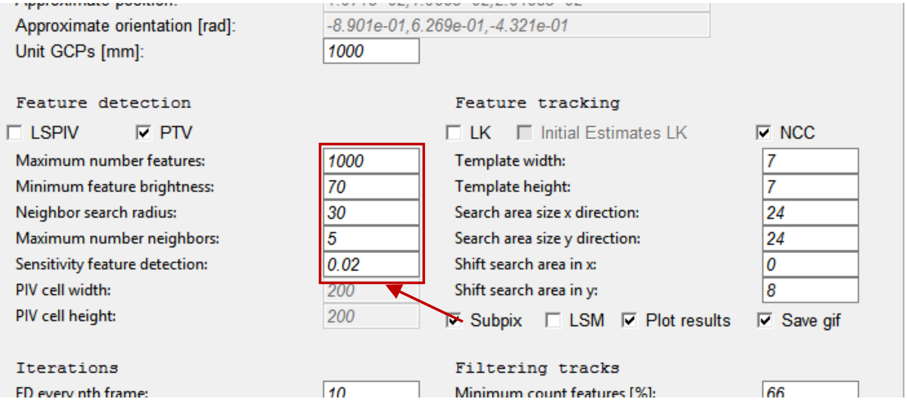
Feature detection

Feature tracking

- "Unit GCPs": Define the unit of the GCPs because all measurements in the FlowVelo-Tool are performed in mm (e.g. therefore also the interior camera geometry has to be provided in mm)
- "Estimate exterior orientation": This parameter has to be checked if the camera pose estimation has to be performed using GCP coordinates measured in object space (e.g. with a total station) and measured in the images

- “Use RANSAC for exterior estimation”: To estimate the camera pose via spatial resection some approximate values of the camera orientation and position are needed. If this information is not provided, check “Use RANSAC for exterior estimation”. This option will also test if there might be outliers in the GCPs and if so, they will not be used for the pose estimation. If “Use RANSAC for exterior estimation” is not checked, you need to type in approximate values of the camera pose (“Approximate position” in X,Y,Z and “Approximate orientation” in omega,phi,kappa).
- Furthermore, it is possible to use a-priori known information of the camera pose only instead of using GCPs to define the exterior orientation. If this is the case, uncheck both “Estimate exterior orientation” and “Use RANSAC for exterior estimation” and type the exterior orientation parameters in the approximate position/orientation fields.

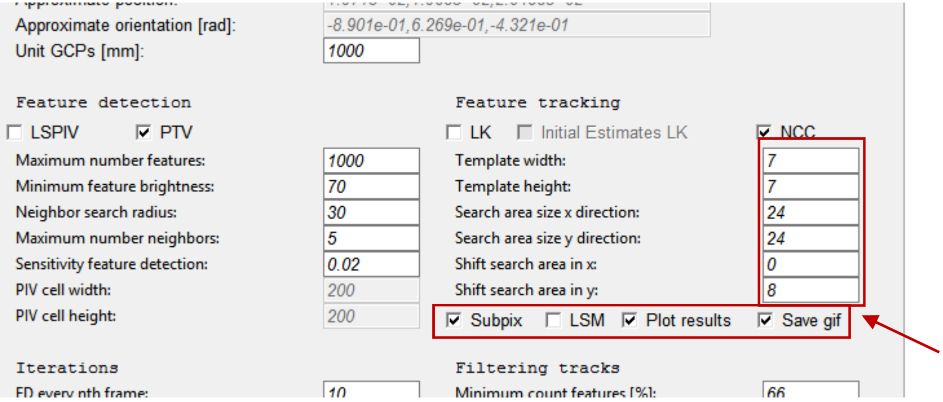
3. Set parameters for feature detection:



Approximate orientation [rad]:	-8.901e-01,6.269e-01,-4.321e-01		
Unit GCPs [mm]:	1000		
Feature detection		Feature tracking	
□ LSPIV	☑ PTV	□ LK □ Initial Estimates LK	☑ NCC
Maximum number features:	1000	Template width:	7
Minimum feature brightness:	70	Template height:	7
Neighbor search radius:	30	Search area size x direction:	24
Maximum number neighbors:	5	Search area size y direction:	24
Sensitivity feature detection:	0.02	Shift search area in x:	0
PIV cell width:	200	Shift search area in y:	8
PIV cell height:	200	☑ Subpix □ LSM ☑ Plot results	☑ Save gif
Iterations		Filtering tracks	
FD every nth frame:	10	Minimum count features [%]:	66

- “Maximum number features”: Define maximum total number of detected good features to track, which will be kept for subsequent filtering steps
- “Minimum feature brightness”: Define the threshold for minimum brightness of a feature to be considered as particle for tracking. The higher the value is chosen, the brighter the feature has to be. Thus increasing this value leads to a decrease of detected features.
- “Neighbor search radius”: Define the threshold for the radius (in pixels), in which nearest neighbours are searched for to perform the subsequent cluster filtering. The higher the value, the more features will be filtered as more features will be included in the next filtering step.
- “Maximum number neighbors”: Define the threshold for how many neighbors are allowed within the previously defined neighbor search radius. The higher the value, the more features are kept.
- “Sensitivity feature detection”: Define the quality level for features to be kept. It considers the quality measure defined by the minimal eigenvalue (corner score). The defined value will be multiplied with the corner score of the best feature and all features with scores below this product will be excluded. The higher the value is chosen, the less features will be detected.

4. Set parameters for feature tracking:



Approximate orientation [rad]: -8.901e-01,6.269e-01,-4.321e-01
Unit GCPs [mm]: 1000

Feature detection

□ LSPIV ☑ PTV

Maximum number features: 1000
Minimum feature brightness: 70
Neighbor search radius: 30
Maximum number neighbors: 5
Sensitivity feature detection: 0.02
PIV cell width: 200
PIV cell height: 200

Feature tracking

□ LK □ Initial Estimates LK ☑ NCC

Template width: 7
Template height: 7
Search area size x direction: 24
Search area size y direction: 24
Shift search area in x: 0
Shift search area in y: 8

☑ Subpix □ LSM ☑ Plot results ☑ Save gif

Iterations

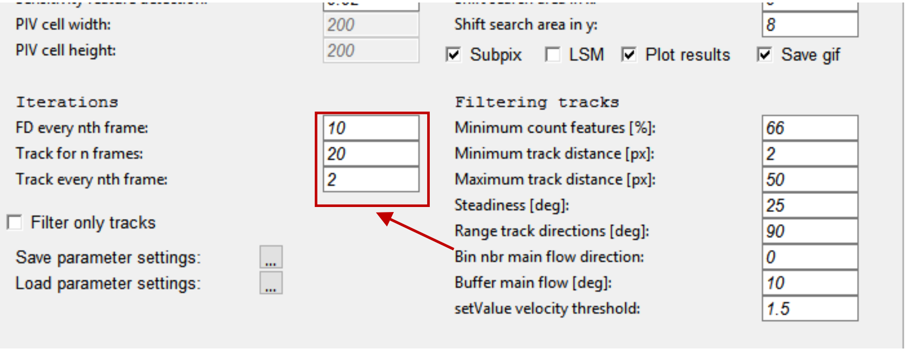
FD every nth frame: 10

Filtering tracks

Minimum count features [%]: 66

- "NCC": Feature matching is performed with Normalized Cross Correlation.
- "LK": Feature matching is performed with Lucas-Kanade approach.
- "Initial Estimate LK": Check this option if LK should use the tracked position as approximate values for the matching in the next frame.
- "Template width": Define the template width (length in x direction of the image). The size has to be odd and is defined in pixels. The wider the template, the longer the processing time but the smaller the chances for ambiguities.
- "Template height": Define the template height (length in y direction of the image). The size has to be odd and is defined in pixels. The higher the template, the longer the processing time but the smaller the chances for ambiguities.
- "Search area size x direction": Define the width of the search area (size in x direction) within which the template is moved to find the corresponding region (e.g. particle). The size is defined in pixels. The higher the value the longer the processing time and the higher the chances for ambiguities.
- "Search area size y direction": Define the height of the search area (size in y direction) within which the template is moved to find the corresponding region (e.g. particle). The size is defined in pixels. The higher the value the longer the processing time and the higher the chances for ambiguities
- "Shift search area in x": Define the approximate flow speed (in pixels) in the x direction to improve matching chances. The higher the flow velocities are, the larger the shifts will be.
- "Shift search area in y": Define the approximate flow speed (in pixels) in the y direction to improve matching chances. The higher the flow velocities are, the larger the shifts will be.
- "Subpixel": Check this option if matching results refined to subpixel accurate positions are aimed for. This step comprises a weighted centroid fit to find the peak location.
- "LSM": This option is still under development. Instead of NCC or LK, matching is performed via least square adjustment. Results are subpixel accurate positions.
- "Plot results": Decide whether results will be plotted.
- "Save gif": Decide whether tracking results will be saved in an animation.

5. Set parameters for repetition of feature detections and duration of feature tracking



PIV cell width: 200
PIV cell height: 200

Shift search area in y: 8
☑ Subpix ☐ LSM ☑ Plot results ☑ Save gif

Iterations
FD every nth frame: 10
Track for n frames: 20
Track every nth frame: 2

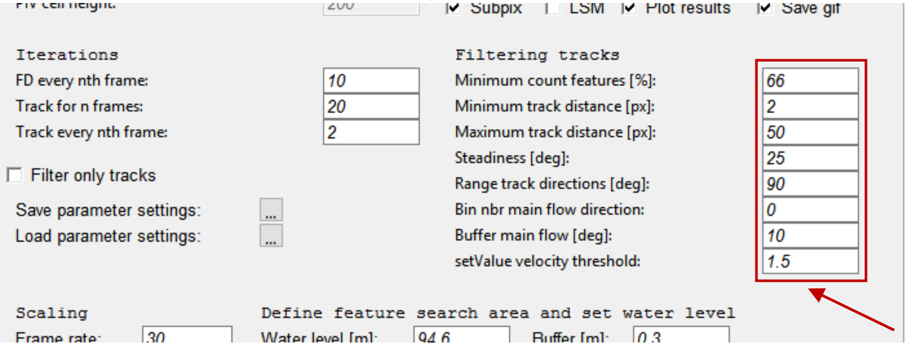
☐ Filter only tracks

Save parameter settings: ...
Load parameter settings: ...

Filtering tracks
Minimum count features [%]: 66
Minimum track distance [px]: 2
Maximum track distance [px]: 50
Steadiness [deg]: 25
Range track directions [deg]: 90
Bin nbr main flow direction: 0
Buffer main flow [deg]: 10
setValue velocity threshold: 1.5

- "FD every nth frame": Define after how many frames new features are detected.
- "Track for n frames": Define across how many frames features are tracked.
- "Track every nth frame": Define how many frames are to be skipped before next matching. For instance, to track features in every frame the value has to be 1, in every second frame 2, every third frame 3), and so on.

6. Set parameters for track filtering:



PIV cell height: 200
☑ Subpix ☐ LSM ☑ Plot results ☑ Save gif

Iterations
FD every nth frame: 10
Track for n frames: 20
Track every nth frame: 2

☐ Filter only tracks

Save parameter settings: ...
Load parameter settings: ...

Filtering tracks
Minimum count features [%]: 66
Minimum track distance [px]: 2
Maximum track distance [px]: 50
Steadiness [deg]: 25
Range track directions [deg]: 90
Bin nbr main flow direction: 0
Buffer main flow [deg]: 10
setValue velocity threshold: 1.5

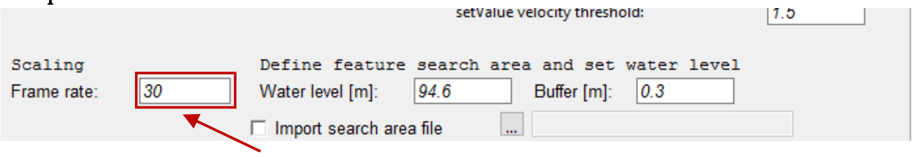
Scaling
Frame rate: 30

Define feature search area and set water level
Water level [m]: 94.6
Buffer [m]: 0.3

- "Minimum count features": Define across how many images a feature has to be tracked minimally to be considered as reliable track. The value is defined in percentage of the total traceable number (i.e. the "Track for n frames" value).
- "Minimum track distance": Define the minimum distance (in pixels), which features have to move between consecutive frames (corresponding to the needed minimum length of a sub-track), thus the track will be considered as reliable track if all sub-tracks are above this threshold.
- "Maximum track distance": Define the maximum distance (in pixels), which features have to move between consecutive frames (corresponding to the allowed maximum length of a sub-track), thus the track will be considered as reliable track if all sub-tracks are below this threshold.
- "Steadiness": Define how strong features can change their direction (in degrees) from one frame to the next (value corresponds to maximum allowed standard deviation of directional changes of all sub-tracks of one track).

- “Range track directions”: Define the maximum range (in degrees) within sub-tracks of a track can change their direction.
- “Bin nbr main flow direction”: To be tested. Should be 0.
- “Buffer main flow”: Define how strong an entire track can deviate from the main flow direction (in degrees), which is calculated as average direction of all track directions.
- “setValue velocity threshold”: A statistical outlier filter; *threshold = mean + setValue * standard deviation*. Define the setValue to calculate a threshold above and below which features are removed. The higher the value, the more tracks are kept.

7. Set parameter to scale velocities:



setValue velocity threshold: 1.5

Scaling

Frame rate: 30

Define feature search area and set water level

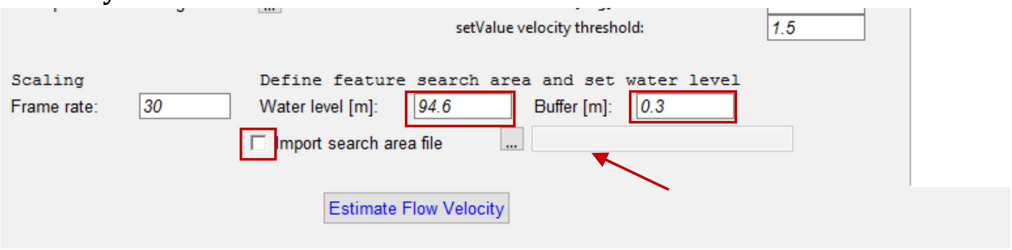
Water level [m]: 94.6

Buffer [m]: 0.3

□ Import search area file

- “Frame rate”: Define the frame rate (in seconds) with which videos or images were captured.

8. Set parameters to define water area (feature search area) and set water level to correctly retrieve 3D coordinates of tracked features:



setValue velocity threshold: 1.5

Scaling

Frame rate: 30

Define feature search area and set water level

Water level [m]: 94.6

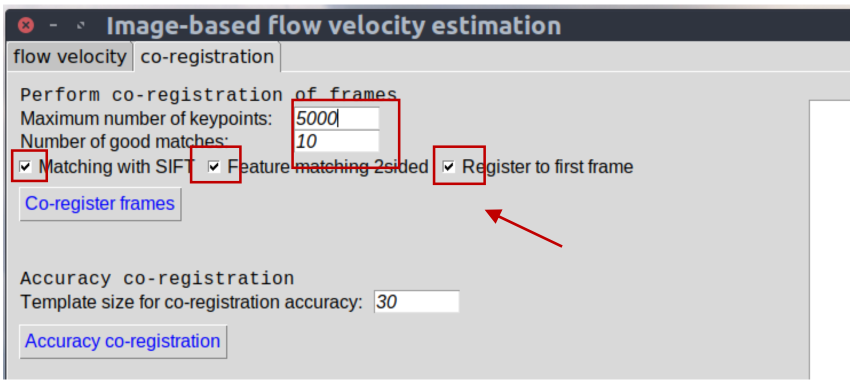
Buffer [m]: 0.3

□ Import search area file

- “Water level”: Define the water level (in m).
- “Buffer”: Define the buffer for the water level, which is needed in very complex terrain or when camera pose estimation is not very accurate to buffer the water-shore borders.
- “Import search area file”: If the feature search area is defined manually (e.g. in GIMP), provide an extent file (ascii txt-file) containing the image coordinates of the border of the mask. The file has to contain two columns (x, y), which are separated by comma.

Short Guideline co-register frames/images:

1. Set parameters
   - "Maximum number of keypoints" set maximum number of detected Harris corner keypoints
   - "Number of good matches" set minimum number of matched keypoints to allow for estimation of homography
   - "Matching with SIFT" if checked uses SIFT feature descriptor, if unchecked uses ORB feature descriptor
   - "Feature matching 2sided" check to increase robustness, but also increases computation time
   - "Register to first frame" if checked registers all frames of sequence to first frame, if unchecked register frame to previous frame



Perform co-registration of frames

Maximum number of keypoints: 5000

Number of good matches: 10

☑ Matching with SIFT ☑ Feature matching 2sided ☑ Register to first frame

Accuracy co-registration

Template size for co-registration accuracy: 30