F1-VIS
F1 Vortex Identification Software
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Introduction

- Focus on vortices generated by the front wing
- Aim: To produce a data mining tool that extracts vortices from CFD data and simplifies them to be compared between simulations

Mesh
Initial concept

- Graph with lines representing the centre of the vortex
Vortex identification with Paraview

- Produced by Kitware
- Open source python library
- Used for visualisation
- Can use a GUI or python script
- Used to get image slices from the CFD data
Image slice visualisation
Definitions

- Total Cp
- Vorticity
- $\Delta$-criterion
- $\lambda_2$-criterion
- Q-criterion
Vortex extraction with ITK/SimpleITK

- Insight Segmentation and Registration Toolkit
- Initially funded by the US National Library of Medicine of the National Institutes of Health
- Open sourced software designed to segment MRI scans
- Divides an image into segments to automatically identify different parts of the brain
- Used to extract vortices
SimpleITK segmentation

Region Growing
(Connected threshold)
Inputs:
- Standard image
- Seed points
- Threshold upper and lower values
Finds all pixels that are ‘connected’ to the seed point that are in the threshold range

Watershed
(Morphological watershed)
Inputs:
- Gradient image
- ‘Water level’

Level Set
(Fast marching)
Inputs:
- Sigmoid image (gradient image)
- Stopping value
- Seed points

ITK Software guide - [https://itk.org/ItkSoftwareGuide.pdf](https://itk.org/ItkSoftwareGuide.pdf)
## Comparison step

<table>
<thead>
<tr>
<th></th>
<th>Connected Threshold</th>
<th>Watershed</th>
<th>Level Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$-criterion</td>
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<td>$\lambda^2$-criterion</td>
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<td>Q-criterion</td>
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<tr>
<td>Total Cp</td>
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<tr>
<td>Vorticity</td>
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</table>
Combinations

Watershed vs Vorticity

Level Set vs Total Cp
Selection step

- Selection results:

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<td>(\Delta)-criterion</td>
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<tr>
<td>(\lambda^2)-criterion</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Total Cp</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Vorticity</td>
<td>2</td>
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<td>2</td>
</tr>
</tbody>
</table>

Key

- Eliminated first
- Eliminated during comparison of segmentation methods
- Made it to the head to head comparison
- Chosen combination

- Next step - develop the chosen combination further
Development of the chosen method

- Connected Threshold vs Q-criterion
- Uses watershed to get the centres of the segments and uses the centres as seeds for the connected threshold
- Identify segments as part of the same vortex or not
vortex_dict =

    { '0001' :
        {'segment' : [list_of_segments],
         'centre'  : [list_of_pixel_centres],
         'xs'      : [list_of_x-coords],
         'ys'      : [list_of_y-coords],
         'zs'      : [list_of_z-coords],
         'image_file': [list_of_image_output_locations],
         'TOTAL_CP': [list_of_total_cp_at_centres]
        },
    }

- Converts pixel location to xyz coordinates
- Easy to write to different formats
Y250 Comparison: same wing different air speed

Coloured by TOTAL_CP
Other geometries
Other geometries
Summary of so far

- Slices up the CFD data and colours planes
- Segments the image to extract vortices
- Finds centres of the vortices and a variable value at this point
- Can export surfaces of the vortices
- Should work on any geometry or set of images
The Future

- Rewrite and add other feature recognition
- Make it smarter
- Data mining - “the process of sorting through large data sets to identify patterns and establish relationships to solve problems through data analysis.”
  [http://searchsqlserver.techtarget.com/definition/data-mining](http://searchsqlserver.techtarget.com/definition/data-mining)
- Machine learning - “an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.”
- Design optimisation
\[ S^2 + \Omega^2 \]

\[ S_{ij} = \frac{1}{2} \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \]

\[ \Omega_{ij} = \frac{1}{2} \left( \frac{\partial u_i}{\partial x_j} - \frac{\partial u_j}{\partial x_i} \right) \]

\[ \Delta = \left( \frac{Q}{3} \right)^3 + \left( \frac{R}{2} \right)^2 > 0 \]