Surge report

Image Processing and 3D Visualization of TSP and IR Thermography Images

Application No- 2330540 Mentor- prof. S.Mariappan

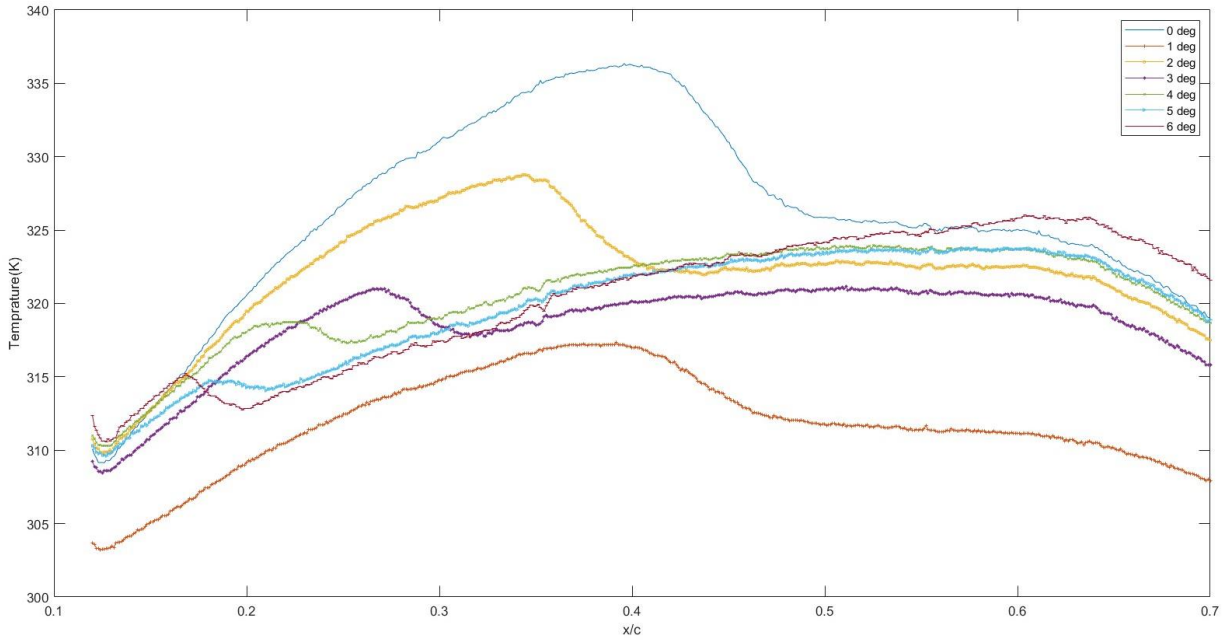
Introduction

To study the flow transition over an airfoil with the help of temperature-sensitive paint(TSP) and infrared imaging on the basis of the temperature variation of the laminar and turbulent regions. This difference is captured on the image of TSP coated airfoil with the help of CCD cameras, from the property of temperature-sensitive paint, it contains luminophores or florescent elements, that emit different intensities of light according to the temperature, it gets excited at a certain wavelength of light and emits light of higher wavelength while returning to ground state but if they are thermally quenched they are at ground state without emitting any light. Another way to measure the temperature difference is by using an infrared camera, it doesn't require TSP coating, and it can give spital and high-temperature resolution compared to the TSP technique, in IR image value of each individual pixel represents the temperature value at that surface. For the TSP image processing, the reference image is required. Reference images are taken at a constant temperature, and the dark image is taken for the correction of the reference image. When the temperature over the airfoil(NACA0015) is locally constant the wind is turned on and the run image is captured, after this, the image processing is applied to the image pairs in order to obtain relatively divided temperature images. These images are then plotted on the 3D surface of the airfoil for further visualization of transition boundaries and to visualize the temperature variation across the surface and also to compare the experimental results with the results obtained from simulation software on the same airfoil model.

Image processing on Infrared (IR) and TSP images

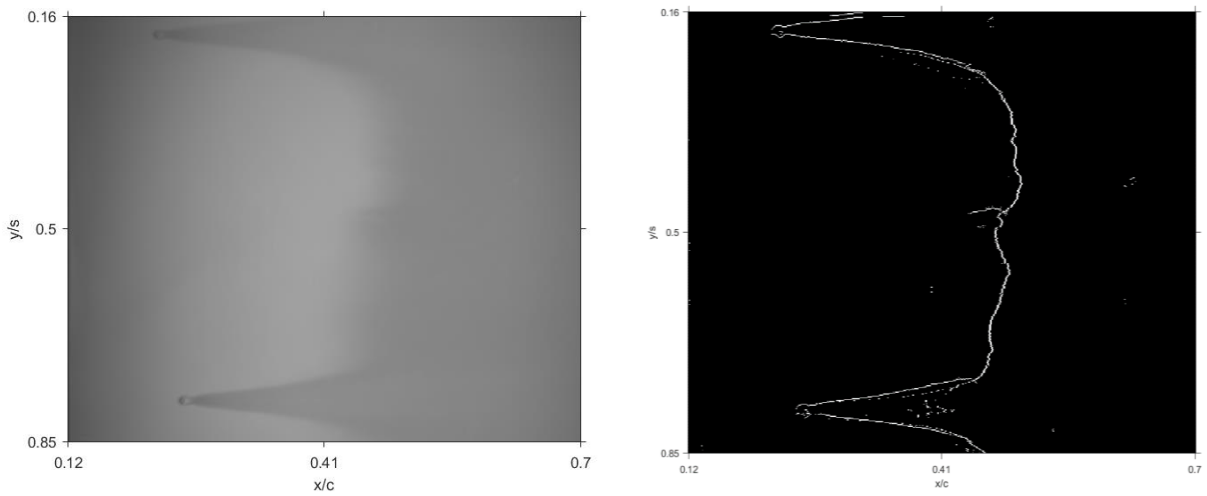
IR Image Processing

The IR thermography image captures a clear temperature variation over the surface with a small amount of noise. IR image contains the temperature value of the surface stored in individual pixels, and each pixel contains the temperature value at the corresponding location to the surface. The Transition Edge on IR images can be easily detected as the temperature difference between the flow separation bobble, laminar zone, and Turbulent reattachment zone is noticeable, it follows a particular trend of temperature variations over the different angles of attack. The normal transition boundary can be determined by locating the abrupt change in temperature. Finding the steepest slope in the temperature variation curve (fig)

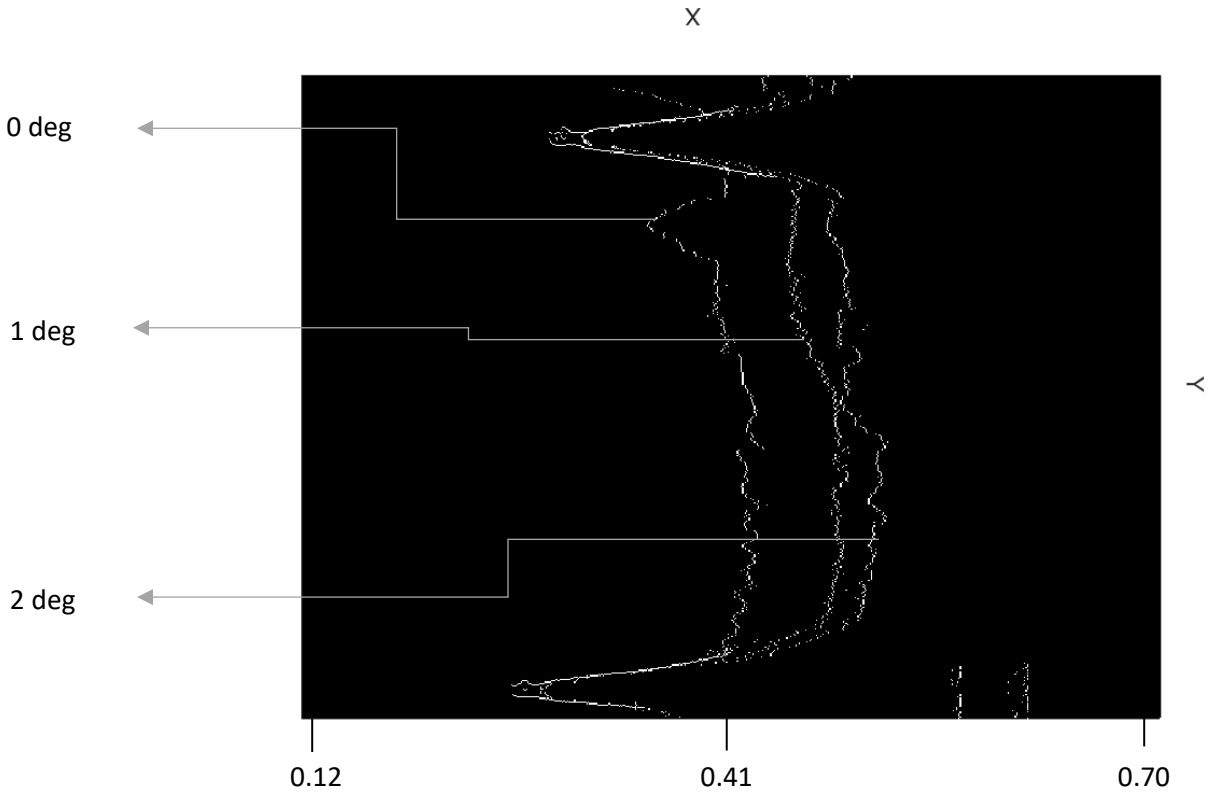


- Temperature vs cord distance at 0.5 y/s location at 35m/s flow speed

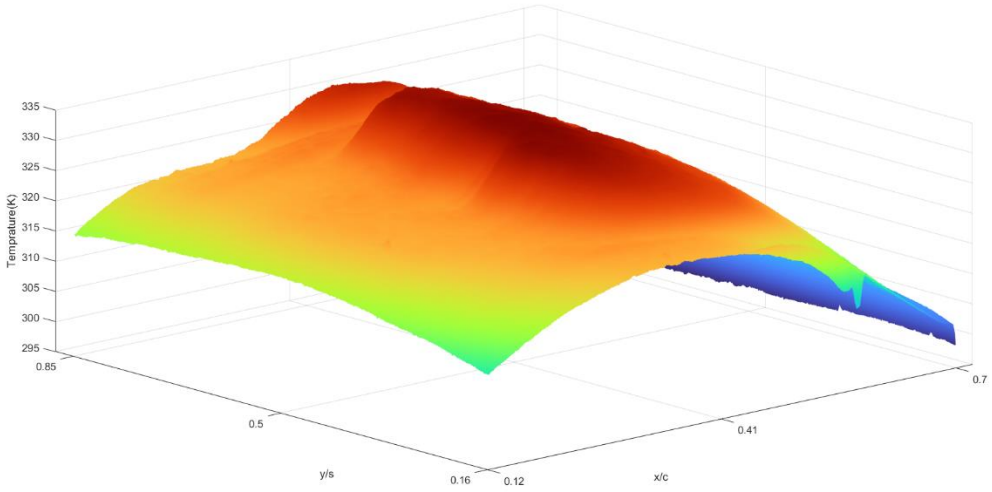
Although the same trend doesn't hold at the forced transition boundary this requires a method of image subtraction in which the image is subtracted by itself with a slight offset and then binarized to get the forced transition edge. The complete edge is obtained by the addition of both the result images.



- Results of Edge detection on IR image of NACA0015 model at 0^0 deg angle of attack with 35 m/s flow speed



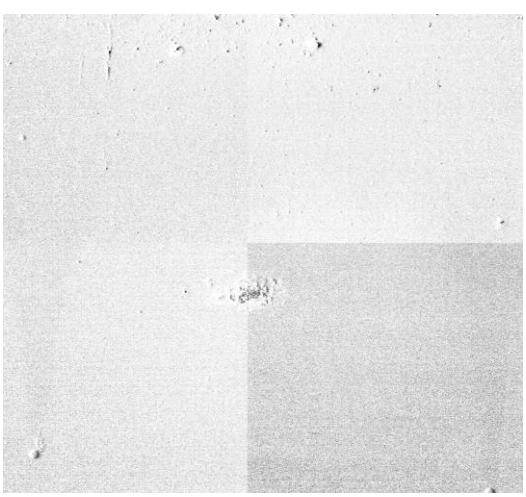
- Results of Edge super imposition of IR image at 0^0, 1^0, and 2^0 deg angle of attack with 35 m/s flow speed

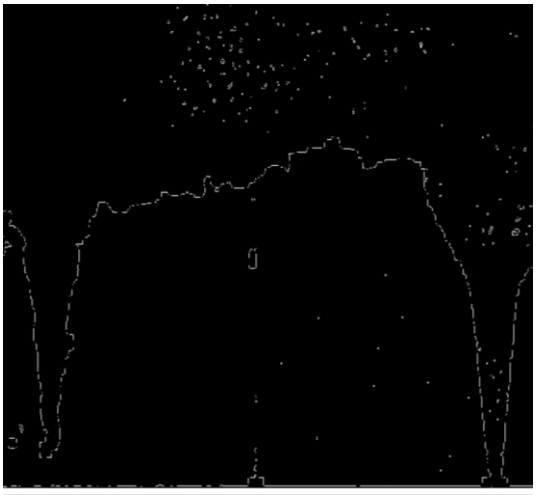


- Results of temperature variation over the surface from IR image at 0^0deg angle of attack with 35 m/s flow speed

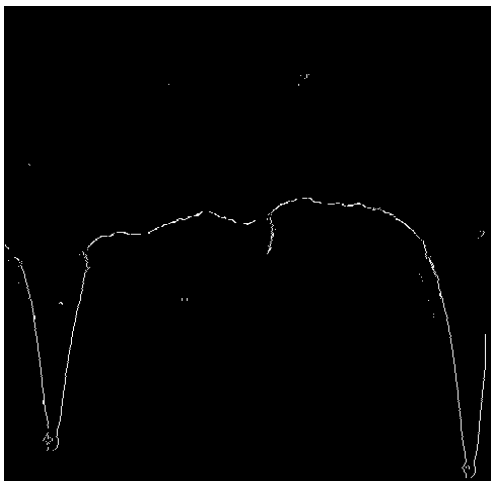
TSP Image Processing

The TSP image requires different methods to process as it does not follow any of the trends as IR images. The TSP image containing some amount of contrast between the laminar and turbulent zone is filtered with a median filter to concentrate the darker and brighter region, the image is then converted to a binary image at some optimum cutoff value. The binary image is processed with noise reduction filters by reducing noise from darker backgrounds and darker patches from brighter backgrounds but this can expense in the degeneration of transition boundaries and result in a noncontinuous edge, to avoid this the noise reduction filter is applied to a section of an image where it will only apply on the section instead of the entire image. The darker patch in the white region is reduced by applying averaging filter and again converting it to a binary image.





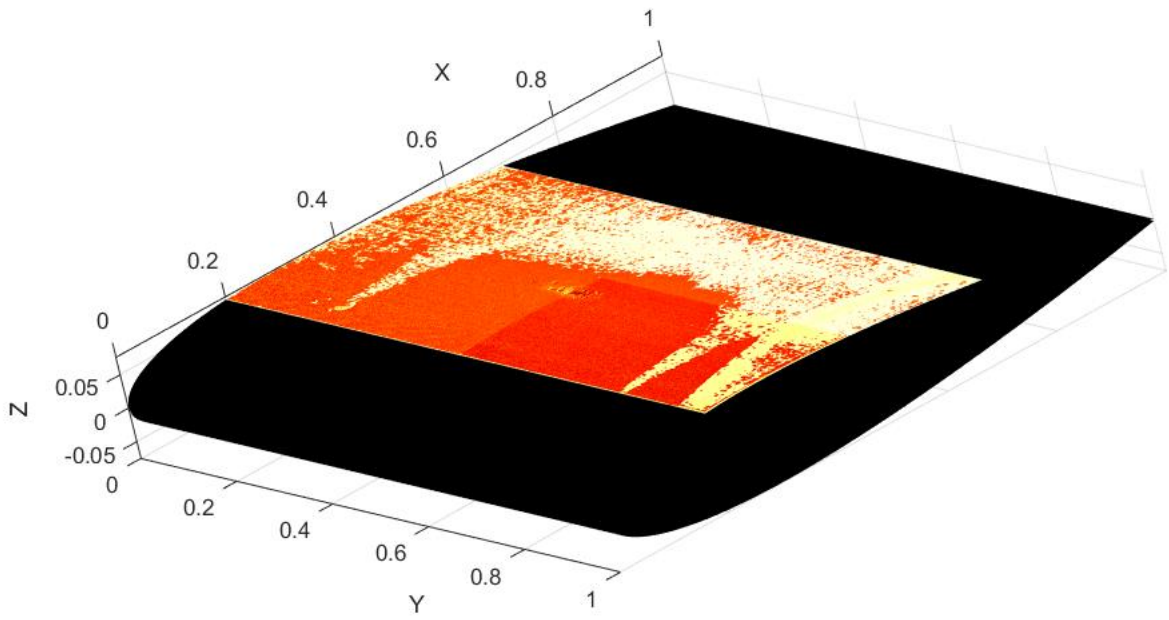
- Results of Edge detection on Temperature sensitive paint (TSP) image of NACA0015 model at 0^0 deg angle of attack at 35 m/s flow speed



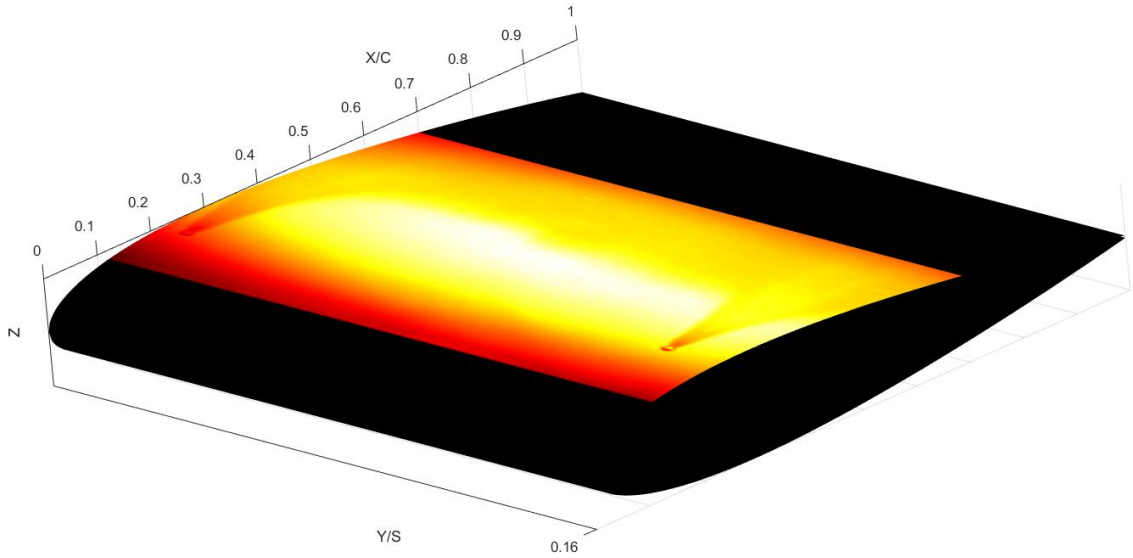
- Results of Edge comparison of TSP image(right) and IR image(left) at 0^0 deg angle of attack at 35 m/s flow speed

3D visualization and mapping

The IR and TSP images are converted to 3D surfaces by using MATLAB surface plotting functions, it takes a mesh grid of the X and Y coordinates and makes the individual surfaces consisting of four points, and each of these individual surfaces represents the Cdata value of an individual pixel of the image, which means the 3D surface of the given image have the same resolution as the image.



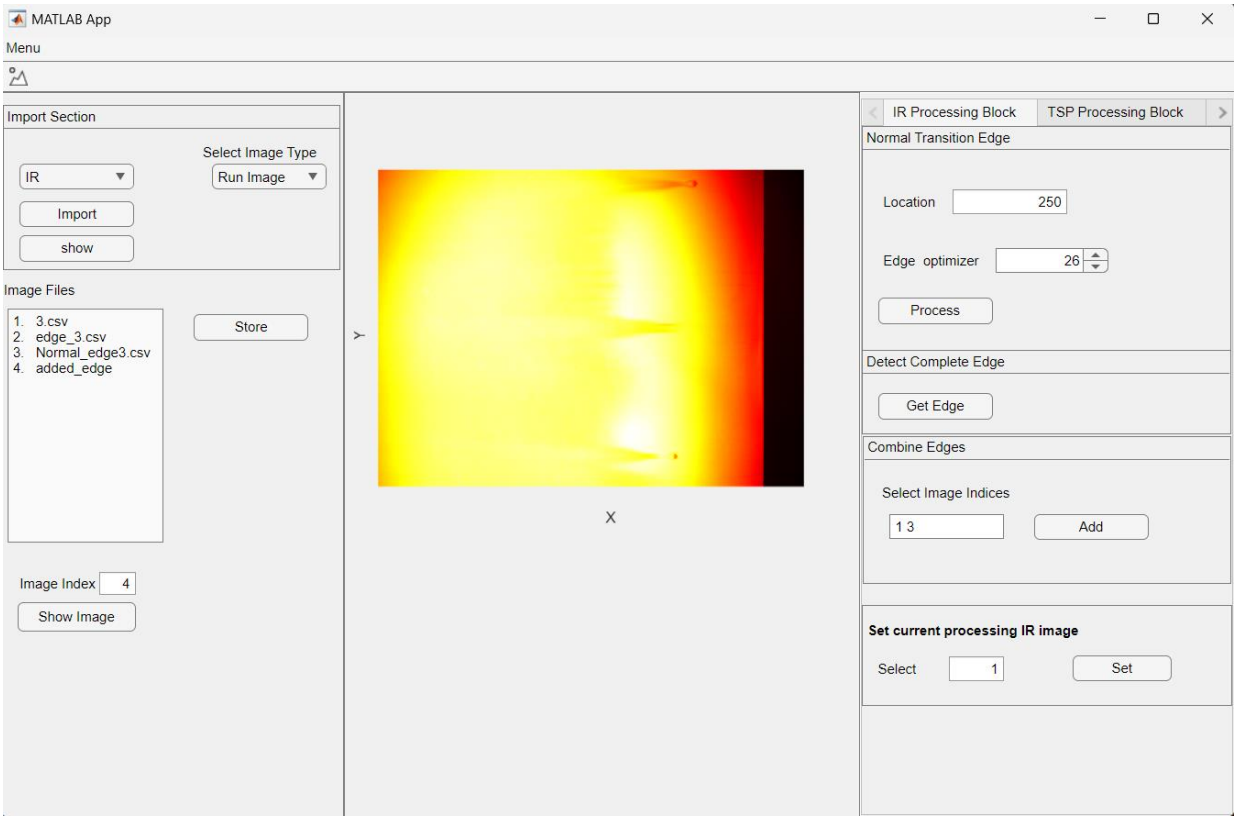
- Results of 3D mapping of Temperature sensitive paint (TSP) image on NACA0015 model at 0^0 deg angle of attack at 35 m/s flow speed



- Results of 3D mapping of Infrared (IR) image on NACA0015 model at 0^0 deg angle of attack at 35 m/s flow speed

Graphical User Interference (using MATLAB)

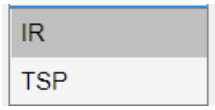
Graphical user interference enables user to use the functions and tools in an easy and more practical way, and provides an efficient way for work flow, the user interference in our scope is to make an image processing tool to process the result data of IR and temperature sensitive paint images for Edge detection and to graphically visualize the temperature variation over the surface and transition edge.

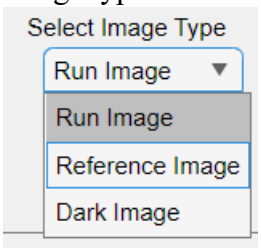


MATLAB application for image processing

To process the image data the user can import the data file from the import section by first selecting the image type (TSP or IR) from a dropdown list, for importing TSP image user need to select the Run image, reference image and dark image separately by selecting toggle button

corresponding to each image type and it will be saved in a temporary memory of the application



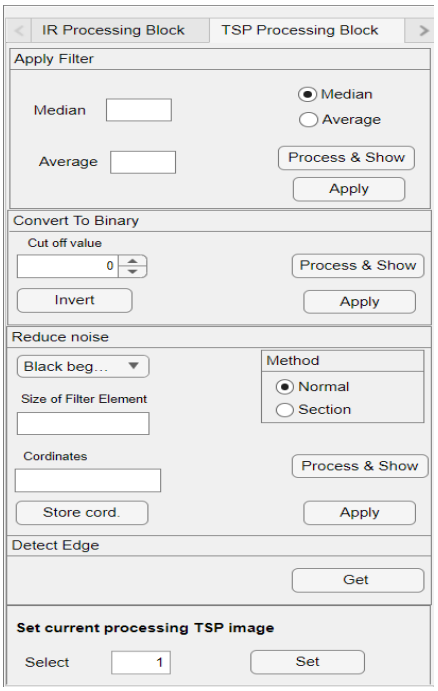


The left panel has the option to store any processed image in the application, with the "Store" button and all the stored images will be visible on the text box named "Image Files" and the file will get its unique index. To call the image from the application's workspace the user has to type the file index to show the image by using the "Show Image" button or to set it as the current processing image.

In the right-hand side panel, there are three tabs named 1. IR Processing Block, 2. TSP Processing Block and 3. Plot 3D

'IR processing block' contains Edge detection tools and an option to superimpose the obtained Edge with different transition Edge using the "Add" button by typing the file indices which is to be added.

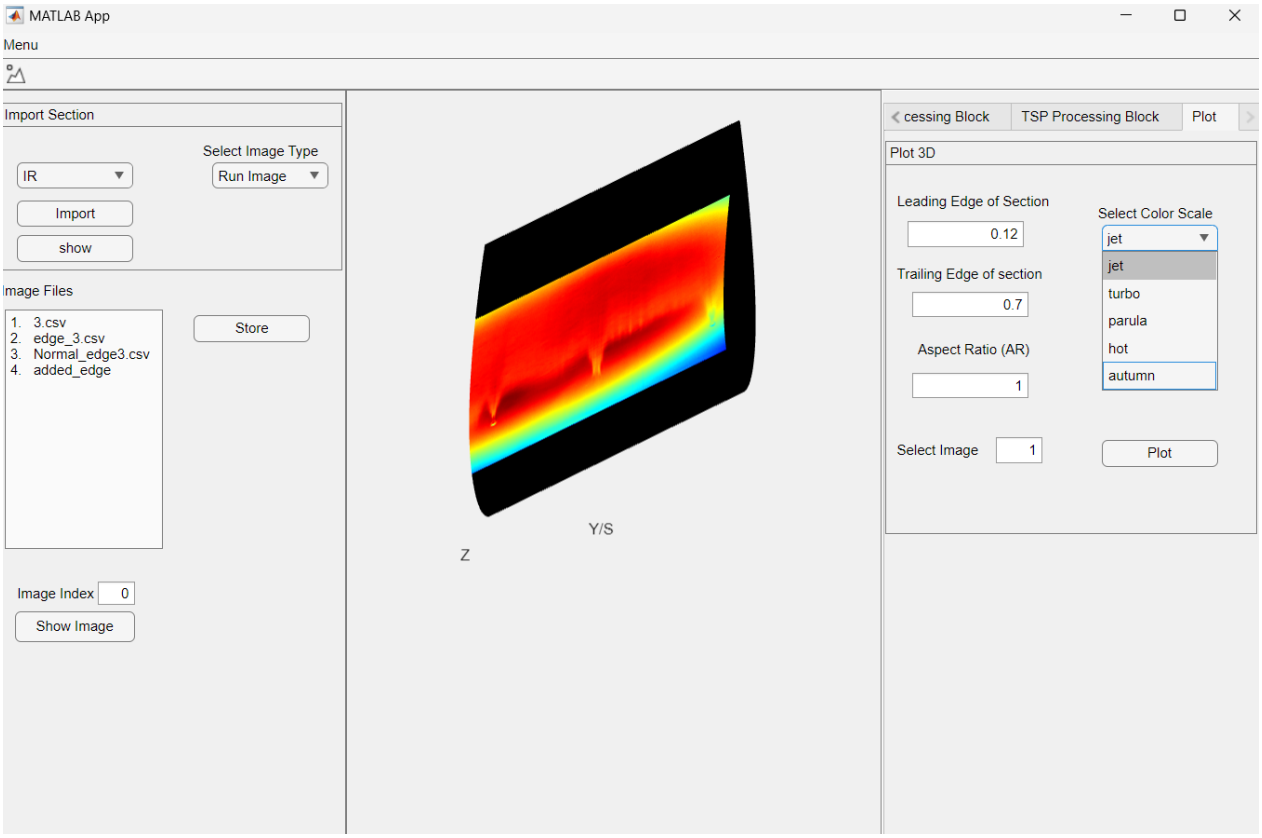
The 'TSP Processing Block' contains image filters edge detecting tools and noise reduction tools to process TSP images.



The imported TSP image is applied to a median filter or average filter by selecting the toggle switch in the "Apply Filter" section and the image can be shown and processed again with the "Process & Show" button, to proceed with further processing and to update the current

processing image by using “Apply” button and same with binarizing image and for noise reduction tools, the processed image can be stored at any stage of processing and the partially processed image can be again processed by setting the current processing image from the ‘Image Files’.

The third tab “Plot 3D” contains functions to plot the selected image on a 3D surface by giving the position details of the selected image.



MATLAB application with Plot 3D command

To plot the image the user, needs to select the image from the “Select Image” option by giving the image index and have to mention the Leading and Trailing Edge section with the Aspect Ratio (AR) of the model. The user can also select the color scale for the image from the” Select Color Scale” drop-down list of mentioned color scales.

Conclusion

TSP and IR image processing was done to extract the laminar to the turbulent transition region.

Transition Edge was detected for images captured at different angles of attack and at different flow speeds condition. For IR images, the transition edge was compared between different edges at the same angle of attack and different flow speeds and at different AOA with the same flow speed.

The Temperature variation was visualized over the surface using IR temperature data at different locations. The IR and TSP images were plotted on the 3D surface of the NACA0015 airfoil model.

A graphical user interference was created for image processing of TSP and IR images.

References

1. Bestek H, Gruber K, Fasel H (1989) Self-excited unsteadiness of laminar separation bubbles caused by natural transition. The Royal Aeronautical Society, In Proc. Conf. on the Prediction and Exploitation of Separated Flows.
2. Sullivan J., " Temperature and Pressure Sensitive Paint", Lecture Series 2000-2001, Advanced Measurement Techniques, Von Karman Institute for Fluid Mechanics, January 2001.
3. Kenneth R. Castleman, *Digital Image Processing*, Prentice-Hall, 1996. ISBN 0-13-211467-4
4. Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, Second Ed, Prentice-Hall, 2001. ISBN 0-20-118075-8
5. Bernd Jahne, *Digital Image Processing*, (Fourth Ed) Springer-Verlag, 1997. ISBN 3-540-62724-3