Abstract

A novel, data-driven filtering technique is developed in this thesis that could provide significant improvement to the way filters have been used traditionally. Starting with a noisy image of blood flow in the cardiac chambers obtained using MRI, the efficacy of the median filter in cleaning the cardiac flow field is initially tested. A method to determine the most effective kernel size for the median filter is first developed using synthetic flow fields and its effectiveness in improving a sequence of MRI acquired cardiac flow field data is demonstrated. The effectiveness of combining a sequence of traditional filters using the best kernel case for each reveals that a median filter followed by Gaussian and Wiener yields similar results for a median filter followed by Wiener and Gaussian. The method has been shown to perform competently in improving the clarity and information extractability of cardiac velocity and vorticity fields. Optimization of kernel size for traditional filters improves visual clarity of images produced by the filtering process. But in spite of that they bring about irreversible loss of information from the images. This is primarily due to two reasons. Firstly, each kernel operation indiscriminately adjusts the value at the central pixel by using values at adjoining pixels without first checking if the adjustment was even necessary. Once the value of the pixel is adjusted, the initial value of the pixel is lost forever since a mechanism for archiving the initial values at the pixels is not available with the traditional filters. To overcome this loss of information, a data-driven, iterative filtering technique is developed in the thesis, which, for a given input image, produces two output images per iteration - (a) a 'filtered image' and (b) an 'outlier image'. The 'filtered image' contains a filtered version of the raw image obtained through selective adjustment of values at the 'bad pixels' while the 'outlier image' stores the values at the 'bad pixels' before they are adjusted. Every iteration produces a pair of such images, an iteration being defined as one complete pass of the convolution kernel over the input image. The size of the kernel, the criteria for determining outlier pixels, and the method of adjusting the values at the outlier pixels are parameters for the filter. Multiple iterations, using fixed parameters, constitute a cascade, and are conducted over an input image till the rate of detection of outliers reaches a threshold or attains a plateau. At that point, the parameters are updated and a new cascade of iterations is run. If the modified Z score of the intensity at a particular pixel is beyond an operator chosen threshold, then that pixel is labelled as 'bad'. Methods for adjusting the values at the 'bad pixels' could range from using a simple average of the good values in the neighbourhood to using surface-fit based advanced regression techniques. The technique is

applied to an image of the far side of the moon, an ultrasound image of a thyroid gland, a selfie image of the James Webb Space Telescope and MRI generated flow data inside the cardiac chambers. Filtered images show kernel size dependent outlier removal, an aspect that could have significant usage in detecting outliers of different scales in low contrast regions of the input image such as the detection of nodules or calcifications in medical images of tissues and organs. The outliers detected and processed in the outlier image for the JWST reveal hidden structures in the source image that are impossible to be detected in the raw image. When applied to cardiac flow data obtained using PC MRI, the technique is found to improve the visual clarity of the cardiac flow field. It is hypothesized that the outlier images for such cardiac PC MRI data, with proper tuning of filter parameters, can help detect subtle structural and functional anomalies in the heart much before they can be detected by conventional methods. Subtle outliers in the flow field, caused by subtle anomalies of structural and functional origin, for example a small damage to a vessel wall, can be detected by the filter as outliers, thereby facilitating the early detection and diagnosis of certain cardiac pathophysiologies.