Digital Image Processing of Plasmas in a Tokamak

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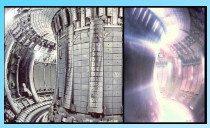
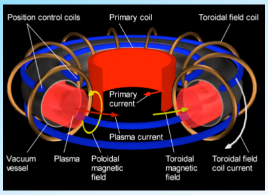
Aim: To obtain well defined and consistent edges from images of filaments of plasma in the Tokamak used for the MAST experiment -- using MATLAB's image processing tools.

A **Tokamak** is a fusion reactor in which the plasma is contained in a toroidal chamber. This is achieved by magnetic fields restraining the plasma on circular loops concentric to the Tokamaks axis.

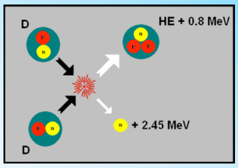




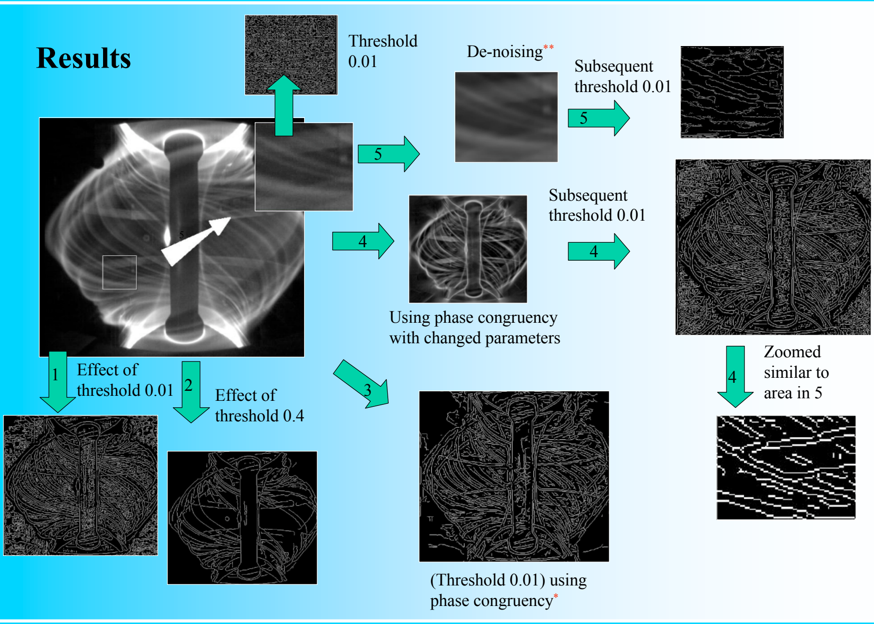
Above, on the left, is a picture of the interior of a Tokamak, partially superimposed with an image of plasma. The other image is a schematic of a Tokamak.

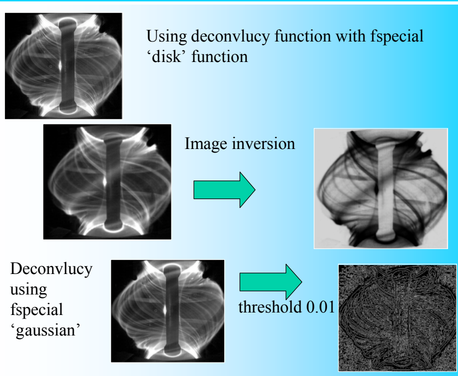
A **plasma** is a fully ionised gas, and so it is affected by magnetic and electric fields. To reach this state it requires massive amounts of energy, and so they maintain a very high temperature. In the MAST experiment the plasma is formed due to the high temperatures (100 million Kelvin) required for deuterium-deuterium fusion to occur. As the amount of energy input in one of these fusion reactions is less than the output, it is hoped that by stabilising the plasma, when in optimum conditions for this process, we will have an efficient and clean energy source.

This is a representation of a deuterium-deuterium fusion, producing helium as well as a neutron .

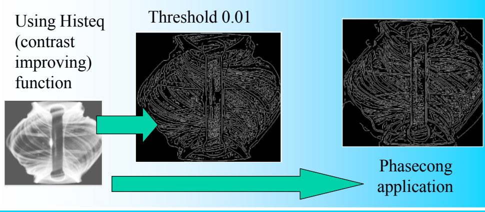


Results





'deconvlucy' is a de-blurring programme. We thought that looking at such methods may help at least clarify the filaments due to the way they appear .



Problem Analysis and Conclusion

• The biggest problem with clearing up these pictures is that the background noise and structure is at times more strongly visible than the plasma itself. This means that at some locations any attempt at isolating the plasma filaments will result only in the removal of the filament itself. This, however, means that at these points the only solution is to remove the filament and artificially recreate it, or ignore it. This would require a programme that can independently identify the filaments correctly and distinguish them from the background noise/structure.

• Knowing that different threshold values of both the *edge* and the *phasecong* functions can alter how much of the finer details are visible, and realising that the thresholds are responsible for this; it seemed sensible to formulate a programme that would split the image into sections, and according to certain specifications of these sections to pick a certain threshold value/variables. Our best results were little different to those produced with selecting single values for the entire image. Since we calculated the specific thresholds for the individual sections only with relation to standard deviation, mean and range of the pixel values in the given section; compared to that of the entire image as well as a set value; it is possible that there is still room for this method to give a little assistance with respect to the *phasecong* function.

• Replacing pixel values beneath a certain threshold value by zero (black) has little positive effect, since although it can help to reduce noise created by the *edge* function outside the plasma, it will damage or even destroy some of the finer filaments, for reasons given above. The *phasecong* filters seem to do the best job thus far at clearing up the image, so a deeper investigation into filters might yield further improvements of the result; and this would seem to be where the most promising results would lie.

Sources: * Phasecong programme – http://www.csse.uwa.edu.au/~pk/Research/MatlabFns/PhaseCongruency/phasecong.m

** Denoising function - http://taco.poly.edu/selesi/DoubleSoftware/image.html