The latest developments in image processing at JET: from information recovery to real time control

by A.Murari[1], J.Vega[2], D.Mazon[3] and JET-EFDA Contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

1) Consorzio RFX-Associazione EURATOM ENEA per la Fusione, I-35127 Padova, Italy.
2) Asociación EURATOM/CIEMAT para Fusión, Madrid, Spain
3) Association EURATOM-CEA, CEA Cadarache, 13108 Saint-Paul-lez-Durance, France Associazione.

*See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea

The increasing penetration of cameras in scientific fields is a clear and uncontroversial trend of the last decades. This evolution has been driven by the simultaneous progress in sensor, optics, electronics and computer technologies. This tendency of relying more on 2-D measurements is particularly evident in large fusion devices, in which many more camera based instruments have become routine diagnostics. An important example of this trend is the Joint European Torus (JET); in the last campaigns many experiments relied on IR and/or visible cameras and about 15 new cameras are being installed for the next experiments with the new ITER-like wall. One of the main characteristics of cameras as diagnostics is the large amount of data that they produce. Again in JET, for example, the new cameras can produce Gbytes of data per shot and already now, out of a global database of more than 90 terabytes of data, about 50% are images. In the perspective of data analysis for control, cameras can also produce images quite difficult to manage and interpret.

For machine protection, the detection of hot spots, regions of the wall with unusually high temperature, is probably the most relevant application of IR cameras. Various algorithmic solutions have already been found and different technological solutions, including the new computational paradigm of Cellular Neural Networks (CNNs) and FPGAs, have been investigated and their performance compared. The application of morphologic operators, using the CNN approach, guarantees deterministic computational time, which is an important ingredient of hard real time applications. Space varying solutions for the CNNs, an original upgrade specifically developed for this application, allow applying different treatments to different parts of the frames. With this new tool a success rate of practically 100 % has been achieved in recognising hot spots without any detrimental effect on the computational time (100 or more frame per second).

Visible videos are affected by strong and rapid variations of the background, mainly due to ELMs, which renders much more difficult the identification of objects in the frames. Therefore more sophisticated approaches, including machine learning tools such as Neural Networks and Support Vector Machines, are proving indispensable to analyse these more complex visible images. Using invariant moments (indicators independent of scale, rotation and position), good progress has already been obtained for the identification of instabilities, such as MARFEs (success rate of the order of 95%), which could provide essential additional information to improve the success rate of disruption prediction techniques.

New methods are also necessary to overcome some technical problems such as the vibrations of the camera fields of views mainly due to ELMs. To automatically identify these movements and to correct them, a new form of non-additive entropy has been successfully applied, reaching a success rate of almost 97%.

Results of the mentioned methods will be presented and the general applicability of the techniques emphasised. The relevance of the various solutions for ITER will be also discussed. In reactor relevant devices, such as DEMO, the proposed methods could also be applied to a wide wavelength range, for example to the Soft X-ray region; imaging in the SXR could indeed

provide a holistic view of the hot reactor relevant plasmas and new technologies, such as GEM detectors and polycapillary lenses are being developed for this purpose.