Second Visualizing Offline and Live Data with AI (VOLDA) Workshop - 2025

Tuesday, 18 November 2025 - Thursday, 20 November 2025

Scientific Programme

Visualization and Digital Twin

Authors are invited to contribute to the areas that delve into the application of **Visualization** and **Digital Twin** technologies in advancing fusion research, particularly in the context of current tokamaks, experimental devices, future fusion reactors, and private-sector fusion initiatives. Submissions should emphasize innovative methodologies and practical insights that leverage these tools to enhance our understanding, monitoring, and optimization of fusion systems. Topics of interest include, but are not limited to:
Digital Twin Development for Fusion: Approaches for building digital twins of current and planned tokamaks and other experimental fusion devices (including private fusion systems) to model plasma behavior, simulate operational scenarios, and optimize performance.
Visualization of Fusion Processes: Advanced visualizationtechniques for representing complex plasma dynamics, magnetic confinement, and reactor operations in public and private sector fusion projects.
Integration of Real-Time Data: Methods to incorporate live diagnostic data into digital twins for predictive maintenance, fault detection, and enhanced operational control of fusion experiments.
ITER, DEMO and Beyond: Conceptual frameworks and case studies on the role of digital twin technologies in the design, testing, and eventual operation of government-led and private fusion next-generation fusion experimental devices and power plants.
Cross-Disciplinary Challenges and Innovations: Addressing issues such as data interoperability, scalability, and computational demands while exploring synergies between fusion research and emerging trends in digital twin and visualization technologies.

Authors should prioritize discussing how these technologies are or can be applied to address key challenges in fusion energy development, improve the efficiency and reliability of experimental devices, and accelerate progress toward achieving sustainable fusion energy. Submissions should highlight practical implementations, novel approaches, and the potential of digital twins and visualization to shape the future of fusion science.

Real-time control

The Real-Time Control topic will focus on the development and implementation of advanced control systems to manage and optimize fusion energy experiments in real-time. This includes leveraging AI-driven algorithms and high-speed data processing to analyze live data streams and enable adaptive responses to changing experimental conditions. Discussions will highlight strategies for integrating real-time data with existing control frameworks while addressing challenges such as latency, reliability, and computational demands. Case studies will showcase how real-time control enhances experiment precision, stability, and overall efficiency, emphasizing its critical role in advancing fusion energy research.

Predictive maintenance

The Predictive Maintenance topic will delve into the use of advanced AI and machine learning techniques to anticipate and address potential equipment failures in fusion energy systems. By leveraging data from sensors, experiments, and historical performance records, predictive maintenance aims to detect anomalies and diagnose issues before they lead to costly downtimes or operational disruptions. This session will explore practical applications, including strategies to extend the lifespan of critical components and optimize maintenance schedules. Case studies from fusion research facilities will highlight successful implementations, demonstrating the value of predictive approaches in enhancing reliability and efficiency in experimental setups.

Big data (incl. smart data retrieval)

Advanced data analysis techniques are necessary to interpret diagnostic data and to extract physical knowledge from the signals. ‘Advanced’ in the fusion context refers to handling large amounts of signals (waveforms and images) and discharges in the most efficient and intelligent way to achieve relevant results.
Managing large number of signals and discharges will provide two important benefits. The first one is that most of the data collected will be used in the analysis. Fusion devices produce tens of thousands of discharges but the analyses are generally carried out with no more than a few tens of shots. The difference of three orders of magnitude between the available data and the actual use makes no sense at present. It is necessary the development of general techniques for the creation of big databases for specialised analysis. It will allow improving the statistical relevance of the results as a consequence of using practically all the information inside the databases. Obviously, the generation of these specific databases should be accomplished in the most automatic way possible. This will provide very significant advantages mainly in two directions: the reduction of human efforts and the standardization of criteria.
A second benefit of considering a large number of signals and discharges is to discover hidden relations in the data. In this respect, data mining techniques should be encouraged. Data mining methods are becoming essential tools in other fields of science and industry and they can provide important advantages in fusion data analysis.
Machine learning methods can be used for pattern recognition in both off-line classification problems and control strategies under real time requirements.
Bayesian statistics is also a very powerful tool for the integration of signals derived by different diagnostics, which are typically used separately and not integrated in a unique best estimator of the physical quantities of interest. This is the matter of integrated data analysis (IDA).
Data Retrieval from fusion databases is an extremely important topic in view of the massive amounts of data generated in the discharges. Instead of asking a database for a signal name and a shot number, the query model has to be moved to ask for a physics event (represented by patterns in signals) and to retrieve the shot numbers and time segments where the event appears.
Among all physical phenomena that appear in thermonuclear plasmas, disruptions always have worried to the fusion community because they are one of the major hazards in fusion. A disruptive instability is a very complex and highly non-linear phenomenon without a clear theoretical model so far. The lack of valid general theory and the crucial need of avoiding its dangerous effects have compelled the development of data driven models. The importance of avoiding, preventing and mitigating disruptions in present and future devices (for instance JT-60SA, ITER or DEMO) motivate further research aimed at detecting early enough not only an incoming disruption but also to determine its type, with the objective of triggering proper avoidance, prevention or mitigation techniques.
According to the preceding paragraphs, research and specific applications of all the above points should be promoted and, therefore, AI Big Data techniques should be further pursued for:

• Creating specialised databases with a large number of discharges by means of data mining techniques

• Increasing the integration of diagnostics by means of IDA

• Smart data retrieval methods

• Developing off-line data-driven models to extract hidden knowledge from the databases

- Developing real-time data-driven models for the recognition of physics events and potential triggering of control actions