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Integration and testing of advanced algorithms for controlling high-energy-density-physics experiments

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The HED community is moving from a single-shot experimental paradigm towards high-repetition-rate (HRR) operations (~0.1 – 10 Hz) that pave the way to develop high-power-laser applications, such as laser-driven secondary radiations sources and inertial fusion energy. To accommodate this paradigm shift, machine learning (ML) and artificial intelligence (AI) algorithms are now being explored for control and optimization of high-energy-density (HED) physics experiments. ML/AI algorithms can be trained to analyze complex diagnostic data [1, 2] to allow for the implementation of fast feedback systems. In ultrashort-pulse, broadband laser systems, control of the spectral phase allows pulse shaping at the femtosecond level [3] and has been used to demonstrate enhancements in particle production [4, 5] for pulse shapes away from the Fourier transform limit (FTL). Integration of ML/AI algorithms with experimental facilities is only beginning with many new regimes to test and explore.

The General Atomics (GA) Laboratory for Developing Rep-rated Instrumentation and Experiments with Lasers (GALADRIEL) [6] serves as a platform for this exploration, providing a test bed to enable rapid development and testing of rep-rated technologies required to address questions in Engineering Science relevant to IFE and other future HRR applications leveraging high-power laser systems. The ~1TW system (~25fs, ~25mJ) has been commissioned and routinely runs experiments at 1Hz, though the laser is capable of 10Hz operation. All experimental data is stored using the MOngoDB Repository for Information and Archiving (MORIA) framework [7], a custom-developed database designed specifically for HRR laser experiments. The database is fully queryable and leverages an organizational strategy that shifts data hierarchy from a shot-based to diagnostic-based approach in order to increase archival and retrieval efficiency when handling large amounts of data. Recent work, in collaboration with the San Diego Supercomputing Center at the University of California San Diego, leveraged remote access to MORIA to utilize large experimental datasets to train ML/AI algorithms for controlling the spectral phase and determining what laser parameters will produce a user-requested pulse shape. Additionally, research efforts at GA have demonstrated the use of Bayesian optimization algorithms for enhancing laser-target interactions using real-time diagnostic measurements. A review of system capabilities will be given, including recent results from demonstration experiments in the areas of advanced pulse-shaping techniques at the femtosecond level, ML/AI-based pulse-shaping control algorithms, and Bayesian optimization of MeV-electron production from laser-gas interactions.

References

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