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Anomaly detection for atomic clocks using unsupervised machine learning algorithms

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Abstract

Atomic clocks are the most accurate timekeeping instruments in the world and play a crucial role in numerous applications, notably in satellite navigation. Nonetheless, the accuracy of these clock signals is subject to anomalies, highlighting the importance of anomaly characterization and detection. In our study, we identify three types of anomalies in the phase data of atomic clocks—outliers, phase jumps and inflection points, and also frequency jumps in the frequency data, which corresponds to the inflection points. The novelty of our work lies in the application of machine learning methods for atomic clock anomaly detection (AD), as opposed to traditional algorithms. We introduce a variety of unsupervised AD and change point detection (CPD) algorithms from the realms of statistics and machine learning, propose a customized thresholding function for AD, and evaluate AD and CPD algorithms on both synthetic and real-world atomic clock data. Our experiments reveal that the subsequence local outlier factor algorithm achieves excellent performance in detecting outliers and phase jumps, but struggles with inflection points. Crucially, we found that the application of a CPD algorithm specifically for detecting the frequency jumps in frequency data substantially improves performance. Our study adopts unsupervised machine learning methods for AD provides robust detection strategies, thereby contributing an expanded understanding of the use of machine learning for clock data monitoring.

Keywords: atomic clock, phase jumps, frequency jumps, anomaly detection, change point detection, machine learning

[3] The work was done during an internship at National Research Council Canada.

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