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Enhancement of Precision Clock Stability and Timekeeping Accuracy of UTC(NPLI) Through Kalman Filter Integration

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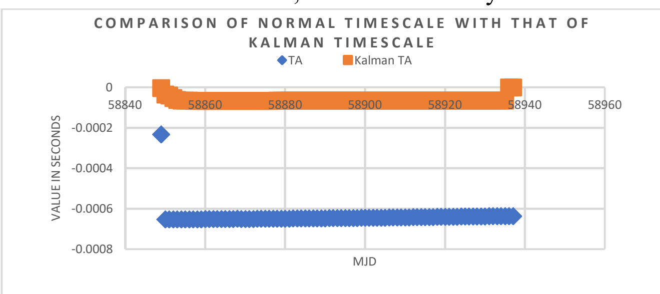
Utilizing a dataset from CSIR-NPL, the research shows promising results by applying Kalman filter on individual clock data, which when combined to form a timescale, significantly improves the performance of developed Timescale.

A highly precise and stable composite timescale is produced in most laboratories using different kinds of atomic clocks. To guarantee the dependability of timekeeping, these laboratories maintain numerous clocks to reduce individual clock inaccuracies and to ensure total reliability [1]. As it averages out the various inconsistencies and assures more excellent stability, accuracy, and dependability beyond the capabilities of any one clock, the method of integrating these clocks' readings is essential [2]. When developing a time scale algorithm, it is crucial to take into account certain essential factors to guarantee its efficiency. Aside from other elements like establishing a weighting process, forecasting clock frequencies, and putting in place a noise-reducing filter, one of the most important parts is determining an average time scale. The weighing technique is a crucial element in which clocks are awarded varying weights based on their performance qualities and historical stability. Kalman filtering has become a crucial mathematical tool to weigh contributions from different clocks, smoothen the data, eliminate noise, and predict the time signal in real time. This is especially crucial to handle clock drift and aging since the filter modifies the timescale to take changes in clock behavior into account and maintain long-term stability.

$$x\left(\frac{t_1+\tau}{t_1}\right) = x\left(\frac{t_1}{t_1}\right) + y_0\,\tau \qquad (1)$$

The above equation predicts the future state x of a clock at time $t_1 + \tau$ given the current state of the same clock at time t_1. The clock offset data was collected over three months from 8 clocks at CSIR-NPL and processed to improve the accuracy and stability of the time scale. The initial investigation mostly involved calculating the average offset data from all clocks for each Modified Julian Day (MJD). Subsequently, we applied the Kalman filter algorithm given above. The findings obtained from the Kalman filter for each clock were saved individually, facilitating a systematic structuring of the outputs. Afterward, the separate outputs were combined to create a composite timescale. The comparison of Normal Timescale with that of Kalman based timescale is shown in figure1 below, where Kalman based timescale shows exceptional improvements. It reaches a range of values between approximately -6.51602E-05 and -6.362E-05, with an extremely low variation of only 1.53899E-06.



1. Jones, A. B., et al. (2022). Advances in Atomic Clock Technologies. Journal of Timekeeping, 35(2), 45-57

2. Tavella, P. and Thoinas, C., 1990, December. Time scale algorithm: Definition of ensemble time and possible uses of the Kalman filter. In Proceedings of the 22th Annual Precise Time and Time Interval Systems and Applications Meeting (pp. 157-170).