Abstract— Few software packages exist which address the particular needs of the time and frequency community in analyzing and simulating clocks or oscillators. None is open source. We offer the source code for a set of tools which aims to incorporate commonly used clock analysis and simulation algorithms. The goal of this release is to promote further development of the package by distributing the effort.

I. FEATURES

The U.S. Naval Research Laboratory (NRL) began development of CANVAS\(^1\) as a package for quick plotting and analysis of all internal as well as various external data related to its clock/oscillator research and development activities. Though written in the MATLAB\(^2\) language, it is anticipated that some routines will likely be rewritten in lower-level languages such as C or FORTRAN to improve speed. All source code is freely available (https://goby.nrl.navy.mil/canvas/). Highlights of the package include standard time-domain variance/covariance calculations, Allan Variance/Covariance, Modified Allan Variance/Covariance, Hadamard Variance/Covariance as well as standard frequency domain periodograms. A rudimentary noise type detection algorithm is also employed. For each variance measure, error bars may be requested which take into account noise type and the appropriate equivalent degrees of freedom [1], [2]. Interactive zooming of the data may be performed, polynomials removed, smoothing algorithms applied, etc. A key feature is that most algorithms are applied only to the data currently visible in the plotting window. Thus, for example, a user may calculate variance measures based on data isolated by zooming onto the desired portion of the overall data series. Also, CANVAS can simultaneously handle multiple time series, either in the same plot, or alternatively in stacked plots (see Fig. 12). A routine to estimate the instabilities of N clocks given N-1 clock difference measurements and taking into account nonzero clock correlations is also included (see [3], [4], and [5]). In addition, CANVAS includes a set of routines for simulating clock/oscillator noise, including pure power-law noise ([6], [7]) as well as fractionally differenced noise processes ([8], [9]). Additional code and sample scripts are also available for integrating other data sources and databases and for building custom dialogs to fit the specific needs of individual users. A web forum has been established to promote further development of CANVAS at https://goby.nrl.navy.mil/canvas/.

The MATLAB source code is included and many routines may be used individually or collectively through the GUI provided. Though CANVAS is written in the MATLAB language, one may obtain executable binary versions of the package, which do not require MATLAB to run. Currently, binary versions are available only for Windows and Linux.

Fig. 1 shows the GUI main figure window for CANVAS with two sample clock series loaded. Analysis functionality is obtained from a quick tool palette along the left of the CANVAS figure, from menus, or from context menus obtained by right-clicking various plot objects. Fig. 2 and Fig. 5 show the accompanying command windows which show various ASCII output from commands. Clicking the pink SPECVAR (specialized variance) button brings up the SPECVAR dialog window as shown in Fig. 3. For each series plotted in the main CANVAS window, a separate line will exist in the SPECVAR dialog where one may adjust various parameters used by the specialized variance measures.

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\(^1\) Trademark and patent pending.

\(^2\) MATLAB is a registered trademark of The Mathworks Inc.
II. CLOCK SIMULATION

Two algorithms (labeled PPL and FD in the radio buttons of Fig. 6) have been included for simulating clock data, the algorithm of Kasdin ([5], [6]) for generating discrete pure power law processes and the Circulant Embedding
The Kasdin algorithm ([7], [8]) for exactly generating fractionally differenced processes. Composite processes may be specified simply by entering more than one (up to 5) power law alpha and the corresponding level of noise. Noise level may be specified either as the Allan deviation at \( \tau = 1 \) s, or as a spectral density by selecting the appropriate radio button (Fig. 6). Some limitations apply here based on the power law chosen. Finally, systematic offsets in phase, frequency drift as well as sinusoids may be added. Figs. 6 and 7 show an example of 5 realizations generated using the Kasdin algorithm with White Frequency (\( \alpha = 0 \)) specified as having an Allan deviation of 1e-12 at \( \tau = 1 \) s and a daily sinusoid of amplitude 1e-11, the data tabulated at 15-minute intervals.

Given the 5 realizations shown in Fig. 7, we may next select the SPECVAR dialog (Fig. 8) for calculating specialized variances. As the dialog above shows, we have selected an Overlapped Allan Deviation for each series and will calculate the deviation at 50 different averaging intervals, \( \tau \), evenly log-spaced. Error bars will be placed on each series. Notice we have also selected that N-cornered hat be performed and we have labeled each reference clock for each series as the same reference, which we’ve called “ref”. Note that labeling a separate reference clock will result in separate N-cornered hat evaluations for each different reference listed. Finally, no noise-type detection has been requested, but instead we will use the default WHITE FM error bars (\( \alpha = 0 \) for each of the 50 intervals) at each \( \tau \). The result of these selections is Fig. 9.

Notice we have the additional deviation for the reference clock as per the N-cornered hat algorithm. Clearly, since each series of Figure 7 was generated with the same 12-hour sinusoid, the N-cornered hat routine correctly identifies this feature as belonging to the reference, as evidenced by the large “hump” at \( \tau = 10,800 \) s (one quarter of the 12-hour period) as well as harmonics in the frequency stability for ref above.
III. DATA ARCHIVING AND RETRIEVAL

The archiving component of CANVAS consists of the open source MySQL® database server (http://www.mysql.com) as well as separate UNIX scripts for downloading and loading various data into MySQL databases/tables. Nearly all NRL data sources, including multiple GPS data sources, in-house clock measurement data, MET data, as well as a myriad of other telemetry data have been incorporated into MySQL in an automated fashion at NRL. Sample UNIX scripts, a single MySQL data source (see IGS Clock Products below), and all NRL data source dialogs have been included in this distribution so that users may have ample examples for building their own databases and CANVAS dialog windows. Users must obtain and install MySQL separately from this package taking note of any license restrictions from MySQL AB.

As a full example of integrating a data source, we have included an International GPS Service (IGS) Clock Products dialog window (see Fig. 10 and the files igsdlg.m and igsdlg.fig), UNIX scripts for parsing & loading Clock RINEX files into MySQL, as well as a MySQL database containing IGS Rapid & Final clock products. Once MySQL is installed, users may either simply copy the IGS MySQL database to the appropriate folder on your MySQL server, or utilize the sample UNIX scripts to obtain the Clock RINEX files from the IGS and build the database manually. The latter solution will ensure that users have the latest data since the UNIX scripts can be scheduled to run regularly.

Note: The C++ mysql.cpp routine which interfaces Matlab and MySQL was written by Robert Almgren at the University of Toronto and permission was granted to include it in this distribution. For more information on this routine, see http://www.mmf.utoronto.ca/resrchres/mysql/.

Figs. 10 & 11 show two different dialogs for importing various data from MySQL into CANVAS. The IGS dialog of Fig. 10 allows one to load IGS Rapid and/or Final clock estimates into CANVAS and should be fully functional for users once the above procedures are taken into account. Fig. 11 shows a dialog for accessing NRL in-house clock measurement data as well as various NRL MET data. Though the source code for Fig. 11 is included (tagntdlg.m & tagntdlg.fig) in the distribution, the data sources are not included and so this dialog will not function for most users. It is included only to show the versatility of the CANVAS design and to provide more examples of dialogs. Fig. 12 shows the resulting data imported by making the selections in the TAGNT dialog as shown in Fig. 11. Notice that MET data were plotted separately from the clock data.

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3 MySQL is a registered trademark of MySQL AB in the United States, the European Union and other countries.
References to specific software in this paper and in the CANVAS distribution do not constitute endorsement by the Department of Defense/U.S. Navy/U.S. Naval Research Laboratory.

REFERENCES


