# CRAN Task View: Time Series Analysis

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Base R ships with a lot of functionality useful for time series, in particular in the stats package. This is complemented by many packages on CRAN, which are briefly summarized below. There is also a considerable overlap between the tools for time series and those in the Econometrics and Finance task views. The packages in this view can be roughly structured into the following topics. If you think that some package is missing from the list, please let us know.

## Basics

- *Infrastructure* : Base R contains substantial infrastructure for representing and analyzing time series data. The fundamental class is `"ts"` that can represent regularly spaced time series (using numeric time stamps). Hence, it is particularly well-suited for annual, monthly, quarterly data, etc.
- *Modeling* : Methods for analyzing and modeling time series include ARIMA models in `arima()`, AR(p) and VAR(p) models in `ar()`, structural models in `StructTS()`, visualization via `plot()`, (partial) autocorrelation functions in `acf()` and `pacf()`, classical decomposition in `decompose()`, STL decomposition in `stl()`, moving average and autoregressive linear filters in `filter()`, and basic Holt-Winters forecasting in `HoltWinters()`.

## Times and Dates

- Class `"ts"` can only deal with numeric time stamps, but many more classes are available for storing time/date information and computing with it. For an overview see *R Help Desk: Date and Time Classes in R* by Gabor Grothendieck and Thomas Petzoldt in R News 4(1) , 29-32.
- Classes `"yearmon"` and `"yearqtr"` from zoo allow for more convenient computation with monthly and quarterly observations, respectively.
- Class `"Date"` from the base package is the basic class for dealing with dates in daily data. The dates are internally stored as the number of days since 1970-01-01.
- The chron package provides classes for `dates()`, `hours()` and date/time (intra-day) in `chron()`. There is no support for time zones and daylight savings time. Internally, `"chron"` objects are (fractional) days since 1970-01-01.
- Classes `"POSIXct"` and `"POSIXlt"` implement the POSIX standard for date/time (intra-day) information and also support time zones and daylight savings time. However, the time zone computations require some care and might be system-dependent. Internally, `"POSIXct"` objects are the number of seconds since 1970-01-01 00:00:00 GMT. Package lubridate provides functions that facilitate certain POSIX-based computations.
- Class `"timeDate"` is provided in the timeDate package (previously: fCalendar). It is aimed at financial time/date information and deals with time zones and daylight savings times via a new concept of "financial centers". Internally, it stores all information in `"POSIXct"` and does all computations in GMT only. Calendar functionality, e.g., including information about weekends and holidays for various stock exchanges, is also included.
- The tis package provides the `"ti"` class for time/date information.
- The `"mondate"` class from the mondate package facilitates computing with dates in terms of months.
- TSAgg provides functions for aggregation of incomplete time series data.

- The tempdisagg package includes methods for temporal disaggregation and interpolation of a low frequency time series to a higher frequency series.

### Time Series Classes

- As mentioned above, `"ts"` is the basic class for regularly spaced time series using numeric time stamps.
- The zoo package provides infrastructure for regularly and irregularly spaced time series using arbitrary classes for the time stamps (i.e., allowing all classes from the previous section). It is designed to be as consistent as possible with `"ts"`. Coercion from and to `"zoo"` is available for all other classes mentioned in this section.
- The package xts is based on zoo and provides uniform handling of R's different time-based data classes.
- Various packages implement irregular time series based on `"POSIXct"` time stamps, intended especially for financial applications. These include `"its"` from its, `"irts"` from tseries, and `"fts"` from fts.
- The class `"timeSeries"` in timeSeries (previously: fSeries) implements time series with `"timeDate"` time stamps.
- The class `"tis"` in tis implements time series with `"ti"` time stamps.
- The package tframe contains infrastructure for setting time frames in different formats.

### Forecasting and Univariate Modeling

- The forecast package provides a class and methods for univariate time series forecasts, and provides many functions implementing different forecasting models including all those in the stats package.
- *Exponential smoothing* : `HoltWinters()` in stats provides some basic models with partial optimization, `ets()` from the forecast package provides a larger set of models and facilities with full optimization.
- *Autoregressive models* : `ar()` in stats (with model selection), FitAR for subset AR models, and pear for periodic autoregressive time series models.
- *ARIMA models* : `arima()` in stats is the basic function for ARIMA, SARIMA, ARIMAX, and subset ARIMA models. It is enhanced in the forecast package via the function `Arima()` along with `auto.arima()` for automatic order selection. `arma()` in the tseries package provides different algorithms for ARMA and subset ARMA models. FitARMA implements a fast MLE algorithm for ARMA models. Package gsarima contains functionality for Generalized SARIMA time series simulation. The mar1s package handles multiplicative AR(1) with seasonal processes. TSTutorial provides an interactive tutorial for Box-Jenkins modelling.
- *ARFIMA models* : Some facilities for fractional differenced ARFIMA models are provided in the fracdiff package. The arfima package has more advanced and general facilities for ARFIMA and ARIMA models, including dynamic regression (transfer function) models. afmtools handles estimation, diagnostics and forecasting for ARFIMA models. `armaFit()` from the fArma package is an interface for ARIMA and ARFIMA models. Fractional Gaussian noise and simple models for hyperbolic decay time series are handled in the FGN package.
- *Transfer function* models are provided by the `arimax` function in the TSA package, and the `arfima` function in the arfima package.
- *GARCH models* : `garch()` from tseries fits basic GARCH models, `garchFit()` from fGarch implements ARIMA models with a wide class of GARCH innovations. bayesGARCH estimates a Bayesian GARCH(1,1) model with t innovations. gogarch implements Generalized Orthogonal GARCH (GO-GARCH) models. The R-Forge project rgarch aims to provide a flexible and rich GARCH modelling and testing environment including univariate and multivariate GARCH packages.

Its webpage has extensive information and examples.

- *Miscellaneous* : ltsa contains methods for linear time series analysis, dlm for Bayesian analysis of dynamic linear models, timsac for time series analysis and control, BootPR for bias-corrected forecasting and bootstrap prediction intervals for autoregressive time series.

### Resampling

- *Bootstrapping* : The boot package provides function `tsboot()` for time series bootstrapping, including block bootstrap with several variants. `tsbootstrap()` from tseries provides fast stationary and block bootstrapping. Maximum entropy bootstrap for time series is available in meboot.

### Decomposition and Filtering

- *Filters* : `filter()` in stats provides autoregressive and moving average linear filtering of multiple univariate time series. The robfilter package provides several robust time series filters, while mFilter includes miscellaneous time series filters useful for smoothing and extracting trend and cyclical components.
- *Decomposition* : Classical decomposition is provided via `decompose()`, more advanced and flexible decomposition is available using `stl()`, both from the basic stats package.
- *Wavelet methods* : The wavelets package includes computing wavelet filters, wavelet transforms and multiresolution analyses. Wavelet methods for time series analysis based on Percival and Walden (2000) are given in wmtsa. biwavelet can be used to plot and compute the wavelet spectra, cross-wavelet spectra, and wavelet coherence of non-stationary time series. It also includes functions to cluster time series based on the (dis)similarities in their spectrum. Further wavelet methods can be found in the packages brainwaver, rwt, waveslim, and wavethresh.
- *Miscellaneous* : signalextraction for real-time signal extraction (direct filter approach). kza provides Kolmogorov-Zurbenko Adaptive Filters including break detection, spectral analysis, wavelets and KZ Fourier Transforms. quantspec includes methods to compute and plot Laplace periodograms for univariate time series. Rssa provides a fast implementation of Singular Spectrum Analysis for decomposition of a time series.

### Seasonality

- *Seasonal decomposition* : the stats package provides classical decomposition in `decompose()`, and STL decomposition in `stl()`. x12 provides a wrapper for the X12 binaries which have to be installed first. x12GUI provides a graphical user interface for x12.
- *Analysis of seasonality* : the bfast package provides methods for detecting and characterizing abrupt changes within the trend and seasonal components obtained from a decomposition. Peak2Trough estimates the peak-to-trough ratio of a seasonal component.
- season: Seasonal analysis of health data including regression models, time-stratified case-crossover, plotting functions and residual checks.
- deseasonalize: Optimal deseasonalization for geophysical time series using AR fitting.

### Stationarity, Unit Roots, and Cointegration

- *Stationarity and unit roots* : tseries provides various stationarity and unit root tests including Augmented Dickey-Fuller, Phillips-Perron, and KPSS. Alternative implementations of the ADF and KPSS tests are in the urca package, which also includes further methods such as Elliott-Rothenberg-Stock, Schmidt-Phillips and Zivot-Andrews tests. The fUnitRoots package also provides the

MacKinnon test. CADFtest provides implementations of both the standard ADF and a covariate-augmented ADF (CADF) test.
- *Cointegration* : The Engle-Granger two-step method with the Phillips-Ouliaris cointegration test is implemented in tseries and urca. The latter additionally contains functionality for the Johansen trace and lambda-max tests. CommonTrend provides tools to extract and plot common trends from a cointegration system.

### Nonlinear Time Series Analysis

- *Nonlinear autoregression* : Various forms of nonlinear autoregression are available in tsDyn including additive AR, neural nets, SETAR and LSTAR models. bentcableAR implements Bent-Cable autoregression. BAYSTAR provides Bayesian analysis of threshold autoregressive models. nlts provides functions for estimating the order of a nonlinear autoregression.
- The *TISEAN project* provided algorithms for time series analysis from nonlinear dynamical systems theory. RTisean provides an R interface to the algorithms and tseriesChaos provides an R implementation of the algorithms.
- *Tests* : Various tests for nonlinearity are provided in fNonlinear and nlts.

### Dynamic Regression Models

- *Dynamic linear models* : A convenient interface for fitting dynamic regression models via OLS is available in dynlm; an enhanced approach that also works with other regression functions and more time series classes is implemented in dyn. dlmodeler provides functions for fitting, analysing and forecasting generalized dynamic linear models. The tslars package applies a dynamic variable selection procedure using an extension of the LARS algorithm. More advanced dynamic system equations can be fitted using dse. Gaussian linear state space models can be fitted using dlm (via maximum likelihood, Kalman filtering/smoothing and Bayesian methods).
- *Time-varying parameter* models can be fitted using the tpr package.
- *Distributed lag non-linear models* are handled via the dlnm package.

### Multivariate Time Series Models

- *Vector autoregressive (VAR) models* are provided via `ar()` in the basic stats package including order selection via the AIC. These models are restricted to be stationary. Possibly non-stationary VAR models are fitted in the mAr package, which also allows VAR models in principal component space. More elaborate models are provided in package vars, `estVARXls()` in dse and a Bayesian approach is available in MSBVAR. fastVAR uses fast implementations to estimate VAR models (possibly with exogenous inputs and sparse coefficient matrices).
- *VARIMA models* and *state space models* are provided in the dse package. EvalEst facilitates Monte Carlo experiments to evaluate the associated estimation methods.
- *Vector error correction models* are available via the urca and vars packages, including versions with structural constraints.
- *Time series component analysis* : Time series factor analysis is provided in tsfa. ForeCA implements forecatable component analysis by searching for the best linear transformations that make a multivariate time series as forecastable as possible.
- *Multivariate state space models* are implemented in the FKF (Fast Kalman Filter) package. This provides relatively flexible state space models via the `fkf()` comment: state-space parameters are allowed to be time-varying and intercepts are included in both equations. An alternative implementation is provided by the KFAS package which provides a fast multivariate Kalman filter,

smoother, simulation smoother and forecasting. Yet another implementation is given in the dlm package which also contains tools for converting other multivariate models into state space form. MARSS fits constrained and unconstrained multivariate autoregressive state-space models using an EM algorithm. All four packages assume the observational and state error terms are uncorrelated.
- *Partially-observed Markov processes* are a generalization of the usual linear multivariate state space models, allowing non-Gaussian and non-linear models. These are implemented in the pomp package.

### Continuous time models

- *Continuous time autoregressive modelling* is provided in cts.
- *Continuous time ARMA model* estimation and simulation is available in ctarma.

### Time Series Data

- Data from Makridakis, Wheelwright and Hyndman (1998) *Forecasting: methods and applications* are provided in the fma package.
- Data from Hyndman, Koehler, Ord and Snyder (2008) *Forecasting with exponential smoothing* are in the expsmooth package.
- Data from Hyndman and Athanasopoulos (2013) *Forecasting: principles and practice* are in the fpp package.
- Data from the M-competition and M3-competition are provided in the Mcomp package.
- Data from Cryer and Chan (2010) are in the TSA package.
- Data from Shumway and Stoffer (2011) are in the astsa package.
- Data from Tsay (2005) *Analysis of financial time series* are in the FinTS package, along with some functions and script files required to work some of the examples.
- TSdbi provides a common interface to time series databases.
- fame provides an interface for FAME time series databases
- AER and Ecdat both contain many data sets (including time series data) from many econometrics text books

### Miscellaneous

- dtw: Dynamic time warping algorithms for computing and plotting pairwise alignments between time series.
- ensembleBMA: Bayesian Model Averaging to create probabilistic forecasts from ensemble forecasts and weather observations.
- fractalrock: Generate fractal time series with non-normal returns distribution.
- GeneCycle and GeneNet: Microarray time series and network analysis.
- hydroTSM and hydroGOF provide functions for analysing and modelling time series in hydrology and related environmental sciences.
- Interpol.T makes hourly interpolation of daily minimum and maximum temperature series. It is useful in climatology when hourly time-series must be downscaled from the daily information.
- paleoTS: Modeling evolution in paleontological time series.
- pastecs: Regulation, decomposition and analysis of space-time series.
- ptw: Parametric time warping.
- RMAWGEN is set of S3 and S4 functions for spatial multi-site stochastic generation of daily time-series of temperature and precipitation making use of VAR models. The package can be used in climatology and statistical hydrology.
- RSEIS: Seismic time series analysis tools.

- rts: Raster time series analysis (e.g., time series of satellite images).
- sde: Simulation and inference for stochastic differential equations.
- surveillance: Temporal and spatio-temporal modeling and monitoring of epidemic phenomena.
- tiger: Temporally resolved groups of typical differences (errors) between two time series are determined and visualized.
- tsModel: Time series modeling for air pollution and health.
- wavethresh: Locally stationary wavelet models for nonstationary time series (including estimation, plotting, and simulation functionality for time-varying spectrums).
- wq: Exploring water quality time series.
- WeightedPortTest provides weighted portmanteau statistics for time series goodness-of-fit testing.

**CRAN packages:**

- AER
- afmtools
- arfima
- astsa
- bayesGARCH
- BAYSTAR
- bentcableAR
- bfast
- biwavelet
- boot
- BootPR
- brainwaver
- CADFtest
- chron
- CommonTrend
- ctarma
- cts
- deseasonalize
- dlm
- dlmodeler
- dlnm
- dse
- dtw
- dyn
- dynlm
- Ecdat
- ensembleBMA
- EvalEst
- expsmooth
- fame
- fArma
- fastVAR
- fGarch
- FGN
- FinTS

- FitAR
- FitARMA
- FKF
- fma
- fNonlinear
- ForeCA
- forecast (core)
- fpp
- fracdiff
- fractalrock
- fts
- fUnitRoots
- GeneCycle
- GeneNet
- gogarch
- gsarima
- hydroGOF
- hydroTSM
- Interpol.T
- its
- KFAS
- kza
- ltsa
- lubridate
- mAr
- mar1s
- MARSS
- Mcomp
- meboot
- mFilter
- mondate
- MSBVAR
- nlts
- paleoTS
- pastecs
- Peak2Trough
- pear
- pomp
- ptw
- quantspec
- RMAWGEN
- robfilter
- RSEIS
- Rssa
- RTisean
- rts
- rwt
- sde

- season
- signalextraction
- surveillance
- tempdisagg
- tiger
- timeDate
- timeSeries
- timsac
- tis
- tpr
- TSA
- TSAgg
- TSdbi
- tsDyn
- tseries (core)
- tseriesChaos
- tsfa
- tslars
- tsModel
- TSTutorial
- urca
- vars
- wavelets
- waveslim
- wavethresh
- WeightedPortTest
- wmtsa
- wq
- x12
- x12GUI
- xts
- zoo (core)

### Related links:

- CRAN Task View: Finance
- CRAN Task View: Econometrics
- R-Forge Project: rgarch
- Time Series Data Library
- TISEAN Project