

L3NAV Systems – MATLAB® TOOLBOXES



GPS SOFTWARE TOOLBOX
(GPS TOOLBOX), version 5 – see page 3

KALMAN FILTERING SOFTWARE TOOLBOX
(MKF TOOLBOX), version 3 – see page 22

RINEX and SP3 SOFTWARE TOOLBOX
(RAS TOOLBOX), version 2 – see page 33

COORDINATE TRANSFORMATIONS SOFTWARE TOOLBOX
(CT TOOLBOX), version 2 – see page 40



MATLAB® GPS SOFTWARE TOOLBOX

USER'S GUIDE AND REFERENCE MANUAL

-- VERSION 5 --



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GPS TOOLBOX

GPS SOFTWARE TOOLBOX for MATLAB®

Version 5



GPS TOOLBOX is a library of MATLAB m-file modules and programs used for the implementation of Global Positioning System (GPS) applications. GPS TOOLBOX enables you to simulate a specific GPS application quickly and easily without the need to code and test the basic GPS algorithms.

Due to the fact that this software tool is primarily addressed to a practicing engineer/professional, effort was made to implement the most efficient algorithms available in the technical literature. When appropriate, more than one module performs the same mathematical computation by using different methods, so you can select the approach that best meets your specific requirements.

The GPS TOOLBOX contains numerous main programs that can be modified to fit specific application needs. Once the model of the application is derived or selected, the practitioner can use the software library to implement and test the validity of the proposed GPS application. The source code is royalty free, i.e. the user can incorporate this software in his/her particular application but is not permitted to resell our software as is or with changes.

All of more than 250 m-files are compatible with MATLAB version 5.0 and higher, and most of them are also compatible with previous versions and Student Edition of MATLAB.

A complete (more than 300-pages) user's guide and reference manual contains detailed documentation for each module/program included in the library. To facilitate the search for a specific function, module/program or input/output file, the manual contains a complete reference table by function as well as lists of all modules, programs in alphabetical order.

There are more than 40 fully explained examples (about 130 pages) with input and output data, and generated plots. In addition, a complete directory containing test examples (softcopy) for all main programs is included.

The major building functions of the GPS TOOLBOX are divided in the following categories:

- GPS related constants and conversion factors
- Angle and coordinate transformations
- Specialized plotting programs
- Specialized statistics related functions
- Special signal processing and Kalman filter functions
- GPS time utilities and related functions
- GPS almanac and other data processing functions
- Trajectory and related utilities
- Satellite position and velocity computation
- Elevation and azimuth determination, and satellite visibility
- DOPs computation, satellite selection and related functions
- Pseudorange and deltarange determination, and related functions
- Determination of user's position and related functions

- RINEX 2 data processing and position determination
- Basic and Advanced RAIM/FDE functions
- GPS receiver evaluation functions.

The MATLAB source code is royalty free, i.e. the user can incorporate this software in his/her particular application but is not permitted to resell the software **as is** or **with changes**.

Here is a summary of the most significant features of GPS Toolbox software:

- all m-file modules and programs are written in MATLAB language/environment
- all m-file modules are free of input/output statements (except, of course, for those utilities that require printed output/graph, if any)
- all m-file modules are provided with detailed documentation, including scope, usage, description of parameters, remarks/notes, references, external MATLAB macros/ modules used, and date of last update
- all m-file main/test programs are provided with detailed documentation, including scope, usage, list of inputs, list of outputs, references, external MATLAB macros/ modules used, and date of last update
- almost all main/test programs are provided with input/output reference data, and several detailed examples are given
- flexibility, user-friendly, and open-ended strategy. An open-ended strategy was followed which means that the user can either complement the GPS Toolbox services with his own functions or, alternatively, use GPS Toolbox functions as add-ons in conjunction with other libraries.

What is new in version 5 of GPS Software Toolbox

Here is the list of main upgrades and changes from the previous version 4:

- Numerous updates of the previous modules and main programs and 31 new modules and main programs; overall there are more than 250 modules and main programs
- An expanded section containing more relevant GPS examples; also section 3 can be used as a tutorial (about 130 pages); an expanded manual of about 300 pages
- An expanded directory containing test examples (softcopy) for all main programs
- New topics included; for example, SP3 format processing and analysis, satellite position/velocity comparison using different data source (Yuma/SEM, RINEX and SP3 formats), GPS satellite visibility and HPL/VPL analysis, determination of user's position error based on selected pseudorange errors.

Computer/Software Requirements:

- IBM hardware compatible PC/386/486 or Pentium with Windows 3.1x or higher, and 640 Kbytes of RAM memory; math coprocessor for faster operation.
- MATLAB version 5.0 or higher; most m-file modules/programs are compatible with previous versions as well as the Student Edition of MATLAB
- optional, MATLAB compiler to generate high performance C code from MATLAB m-files, and additional MATLAB toolboxes.

Technical Support:

- free technical support by e-mail or fax to any licensed user, for a year (with possible extension)
- future versions and updates to keep users current with the latest GPS TOOLBOX developments to any licensed user.

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GPS related constants and conversion factors

convcon most used conversion constants
gpscon most used GPS constants
prn2svn PRN to SVN number conversion
pz90con most used PZ-90 constants
sgs85con most used SGS-85 constants
svn2prn SVN to PRN number conversion
wgs72con most used WGS-72 constants
wgs84con most used WGS-84 constants
xcon main program displaying constants specified in macros convcon,
gpscon, pz90con, sgs85con, wgs72con, and wgs84con
xprnsvn main program performing the conversion from/to PRN to/from SVN
numbers

Angle transformations

tadmsrad degrees/minutes/seconds to radians
taraddms radians to degrees/minutes/seconds
xatransf main program executing angle transformations from/to
degrees/minutes/seconds to/from radians (by selection)

Coordinate transformations - Point transformation

tecefgd ECEF to geodetic coordinates (direct method)
tecefgd2 ECEF to geodetic coordinates (iterative method)
tecefgd3 ECEF to geodetic coordinates (direct efficient method)
tgdecef geodetic to ECEF coordinates
xecef2gd_ main program executing comparison between three ECEF to
comp geodetic transformation methods
xptransf main program executing transformations from/to ECEF/geodetic
to/from geodetic/ECEF coordinates

Coordinate transformations - Matrix transformation

mbllw GPS body to LLW (Local Level Wander azimuth)
mecefeci ECEF (Earth Centered Earth Fixed) to ECI (Earth Centered
Inertial)
mecefenu ECEF (Earth Centered Earth Fixed) to ENU (East, North, Up)
mecefins ECEF (Earth Centered Earth Fixed) to INS (Wander/ North, West,
Up)
meceflw ECEF (Earth Centered Earth Fixed) to (Local Level Wander
azimuth)
meciecef ECI (Earth Centered Inertial) to ECEF (Earth Centered Earth
Fixed)
menuecef ENU (East, North, Up) to ECEF (Earth Centered Earth Fixed)
menullw ENU (East, North, Up) to LLW (Local Level Wander azimuth)
minsecef INS (Wander / North, West, Up) to ECEF (Earth Centered Earth
Fixed)
mllwb LLW (Local Level Wander azimuth) to GPS body
mllwecef LLW (Local Level Wander azimuth) to ECEF (Earth Centered Earth
Fixed)
mllwenu LLW (Local Level Wander azimuth) to ENU (East North Up)
xmtransf main program generating matrix transformations specified in the
above mentioned list (by selection)

Coordinate transformations - Vector transformation

vbllw GPS body to LLW (Local Level Wander Azimuth)
vecefeci ECEF (Earth Centered Earth Fixed) to ECI (Earth Centered
Inertial)
vecefenu ECEF (Earth Centered Earth Fixed) to ENU (East, North, Up)
vecefgd ECEF (Earth Centered Earth Fixed) to Geodetic (latitude,
longitude, altitude) for a given position vector and a reference
point
vecefins ECEF (Earth Centered Earth Fixed) to INS (Wander/North, West,
Up)
veceflw ECEF (Earth Centered Earth Fixed) to LLW (Local Level Wander
azimuth)
vecefp90 ECEF (Earth Centered Earth Fixed) to PZ-90 (Parametri Zemli
1990)

vecefs85 ECEF (Earth Centered Earth Fixed) to SGS-85 (Soviet Geodetic System 1985)

veciecef ECI (Earth Centered Inertial) to ECEF (Earth Centered Earth Fixed)

venuecef ENU (East, North, Up) to ECEF (Earth Centered Earth Fixed)

venugd ENU (East, North, Up) to Geodetic (latitude, longitude, altitude) for a given position vector and a reference point

venullw ENU (East, North, Up) to LLW (Local Level Wander azimuth)

vgdecef Geodetic (latitude, longitude, altitude) to ECEF (Earth Centered Earth Fixed), for a given position vector specified by the external points in geodetic coordinates

vgdenu Geodetic (latitude, longitude, altitude) to ENU (East, North, Up) for a given position vector specified by the external points in geodetic coordinates

vinsecef INS (Wander / North, West, Up) to ECEF (Earth Centered Earth Fixed)

vllwb LLW (Local Level Wander azimuth) to GPS body

vllwecef LLW (Local Level Wander azimuth) to ECEF (Earth Centered Earth Fixed)

vllwenu LLW (Local Level Wander azimuth) to ENU (East North Up)

vp90ecef PZ-90 (Parametri Zemli 1990) to ECEF (Earth Centered Earth Fixed)

vs85ecef SGS-85 (Soviet Geodetic System 1985) to ECEF (Earth Centered Earth Fixed)

xvtransf main program executing vector transformations specified in the above mentioned list (by selection)

=====

Specialized plotting programs

xpbar bar graph for a selected column

xplot_map plot selected map area defined by longitude-latitude limits

xworld_map plot world map

xyp1 x-y graph for a selected column

xyp1s x-y graph for a selected column, with statistics

xyp2w x-y graph for two selected columns in two different windows/subplots, with statistics

xyp3w x-y graph for three selected columns in three different windows/subplots, with statistics

xypc2 x-y graph of the difference between columns (from different files), with statistics

xypc2rss x-y graph for RSS (root sum square) of the difference of three columns from two files, with statistics

xypm x-y graph for the selected multiple columns

xyprrs x-y graph for RSS (root sum square) of three selected columns, with statistics

xyprrs2w x-y graph for RSS (root sum square) of three selected columns corresponding to position and velocity errors, in two windows/subplots, with statistics

xypvstd x-y graph for a selected column and the associated envelope (standard deviation), with statistics

=====

Specialized statistics related functions

cep circular error probable (CEP)

cep_pindex computation of CEP based on HDOP and UERE values, and the probability index

prob computation of the probability to have all points within a specified radius for the one-dimensional normal distribution, two-dimensional Raleigh distribution, and three-dimensional Maxwell distribution.

rms root mean square (RMS) of a sample

rms2 modified root mean square (RMS) of a sample (mean of the sample is assumed to be zero)

rss root sum square (RSS) of a three component vector sample

rssxy root sum square (RSS) of a two component vector sample

statup running mean, standard deviation and root mean square (rms)

vcp vertical error probable (VEP)

xcep_pindex main program computing the value of circular error probable (CEP) based on HDOP and UERE values, and the probability index

xcepvcp main program determining the CEP or VEP of a specified data set

xprob main program determining the probability to have all points within a specified radius for the one-dimensional normal distribution, two-dimensional Raleigh distribution, and three-

	dimensional Maxwell distribution
xstat	main program testing the macros: rms, rss, rssxy, and statup
xstate	main program determining the mean, standard deviation and rms of the elements of a specified column
=====	
	Specialized signal processing and Kalman filter functions
dcmnorm	normalization of the direction cosines matrix
genrn	random numbers with normal (Gaussian) distribution, with mean and standard deviation specified
gmp1	first order Gauss-Markov sequence
gmp2	second order Gauss-Markov sequence
kfcov	Kalman filter covariance matrix by using conventional formulation
kfcova	Kalman filter covariance matrix by using alternate conventional formulation
rwalk	random walk process
xgenrn	main program generating the random numbers with normal (Gaussian) distribution and plotting the generated sequence, histogram, and the normalized auto-correlation sequence
xgmp1	main program generating first order Gauss-Markov sequence and plotting the generated sequence and the normalized auto-correlation sequence
xgmp2	main program generating second order Gauss-Markov sequence and plotting the generated sequence and the normalized auto-correlation sequence
xkfcov	main program performing the covariance analysis by using the conventional or alternate conventional Kalman filter formulation
xrwalk	main program generating the random walk process and plotting the generated sequence and the normalized auto-correlation sequence
=====	
	GPS Time Utilities and related functions
cday	determination of the civil day (year, month, day, hour and fraction) from a specified modified Julian day (with fraction)
doy2ymd	determination of civil date (year, month, day) from day of year and specified year
gpslsec	UTC leap seconds value for a specified year between 1980 and 2059
leapyear	determination of the leap year value
mjday	determination of the modified Julian day from the civil day (year, month, day, hour and fraction)
timetr	determination of GPS time of transmission based on time of measurement (reception)
ymd2doy	determination of day of year for a specified civil date (year, month, day)
ymd2doy2	determination of day of year for a specified civil date (year, month, day) - different algorithm
ymd2gps	determination of (GPS week, GPS roll number, day of week) from (year, month, day)
xgpslsec	main program determining UTC leap seconds value for a specified year between 1980 and 2059
xgpstime	main program executing GPS time related transformations
=====	
	GPS Almanac and other data processing functions
elimcol	elimination of a specified column of a two dimensional array
elimrow	elimination of a specified row of a two dimensional array
msc2f	symmetric matrix storage transformation from compact form (upper triangular part, column-wise, one-dimensional array) to full form (all elements, two-dimensional array)
msf2c	symmetric matrix storage transformation from full form (all elements, two-dimensional array) to compact form (upper triangular part, column-wise, one-dimensional array)
selectd	selection of the different elements from a specified array
xelimrc	main program testing the elimination of a specified row/column (see macros elimrow and elimcol)
xmisdat	main program determining the missing data into a specified column of an input data table
xread_sem	main program reading SEM almanac data and creating two data files
xread_yuma	main program reading Yuma almanac data and creating two data files
xread_yuma_	main program reading Yuma almanac data and creating two data

expanded files; executing plots of mean anomaly versus right ascension, inclination angles, and argument of perigee versus right ascension, for all satellites
 xsortrec main program sorting the records based on the elements of a specified column (in ascending order)

Trajectory and related utilities

gcnav great circle navigation position, velocity, acceleration
 geodes geodetic data for a specified departure-destination pair
 geoidh WGS-84 geoid height correction
 gridwaas generation of longitude-latitude WAAS grid
 hpe horizontal position error (range) when latitude and longitude of two points are specified
 trajsv vehicle trajectory in straight segment with constant speed
 xgcdr main program determining great circle dead reckoning trajectory
 xgcnv main program determining great circle navigation position, velocity and acceleration
 xgeodes main program determining geodesic when the departure and destination points are specified
 xgeoidh main program determining WGS-84 geoid height correction, and executing a contour map
 xgridw main program plotting the longitude-latitude WAAS grid
 xhpe main program determining the horizontal position error (range)
 xppva main program determining acceleration from position/velocity data, and plotting all relevant trajectory information
 xppvaj main program determining acceleration and jerk from geodetic position and ENU velocity data, and plotting all relevant trajectory information
 xppvaj2 main program determining acceleration and jerk from ECEF position and ECEF velocity data, and plotting all relevant trajectory information
 xtrajsv main program determining the vehicle trajectory with straight segment and constant speed

Satellite position and velocity computation

svpalm ECEF satellite position based on almanac data
 svpeph ECEF satellite position based on ephemeris data
 svpvalm ECEF satellite position and velocity based on almanac data
 svpvpeph ECEF satellite position and velocity based on ephemeris data
 xsvpalm main program determining ECEF satellite position based on almanac data
 xsvpcomp main program determining RSS satellite position difference based on ephemeris and almanac data, and executing the corresponding graph
 xsvpeph main program determining ECEF satellite position based on ephemeris data
 xsvpvalm computation of ECEF satellite position and velocity based on almanac data; WGS-84 constants are used
 xsvpvcomp computation of RSS between ECEF satellite position/velocity based on ephemeris and almanac data; WGS-84 constants are used
 xsvpvpeph computation of ECEF satellite position and velocity based on ephemeris data; WGS-84 constants are used

Elevation and azimuth determination, and satellite visibility

eleva elevation angle and the ECEF unit line-of-sight vector
 elevar elevation angle, the ECEF unit line-of-sight vector, and the range
 elevaz elevation angle, azimuth angle, the ECEF unit line-of-sight vector and range
 range range between two position points
 uverv unit vertical vector for a given ECEF position vector
 xelaz main program determining elevation and azimuth angles for specified users, time interval, and all satellites in view
 xpelaza main program executing the azimuth-elevation plot for all satellites in view, and the number of visible satellites plot
 xpelazs main program executing graphs related to elevation and azimuth angles for a specified satellite and selected user (input file can be generated by xelaz)
 xsv_ main program determining satellites visibility when several selections are available: almanac or ephemeris, static or dynamic trajectory, elevation mask angle and time interval
 visibiity

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DOPs computation, satellite selection and related functions
dop1      dilution of precision (DOP) quantities when at least 3 line-
of-sight unit vectors are specified
dop2      dilution of precision (DOP) quantities when 4 line-of-sight
unit vectors are specified
gdopv     approximate geometric dilution of precision (GDOP) when four
line-of-sight unit vectors are specified
hmat      H matrix based on line-of-sight measurements
hmatb     H matrix based on line-of-sight and baro measurements
hmatbc    H matrix based on line-of-sight, baro and clock measurements
hmatc     H matrix based on line-of-sight and clock measurements
svsel4    selection of a set of 4 satellites based on minimum GDOP
svsel5    selection of a set of 5 satellites based on minimum GDOP
svsel6    selection of a set of 6 satellites based on minimum GDOP
wdop1     weighted dilution of precision (WDOP) quantities when at
least 3 line-of-sight unit vectors and the corresponding
weighting factors are specified
wdop2     weighted dilution of precision (WDOP) quantities when 4
line-of-sight unit vectors and the corresponding weighting
factors are specified
wdopv     weighted dilution of precision (WDOP) quantities when 4 line-
of-sight unit vectors and the corresponding weighting factors
are specified
xdop      main program determining dilution of precision (DOP)
quantities by using 2 methods
xgdopv    main program determining an approximate value of the
geometric dilution of precision (GDOP)
xhmatal1  main program testing the construction of the H matrix based
on line-of-sight, baro and clock measurements
xmapdop   main program determining repartition of number of visible
satellites and the corresponding DOPs for a specified
geographical area
xmapdop2  main program determining and plotting the repartition of the
number of visible satellites and the corresponding dops for a
specified geographical area, and histogram of the number of
visible satellites
xsvsel    main program executing the selection of 4, 5 or 6 satellites
based on minimum GDOP, and the computation of the
corresponding DOP quantities
xwdop     main program computing the weighted dilution of precision
(WDOP) quantities when at least 3 line-of-sight unit vectors
and the corresponding weighting factors are specified
xwdopv    main program computing the weighted dilution o f precision
(WDOP) quantities when 4 line-of-sight unit vectors and the
corresponding weighting factors are specified
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Pseudorange and Delta range determination and related functions
ionoc     L1 iono correction computation by using Klobuchar model
ionocon   setting of Klobuchar model iono constants
pionoc    pseudorange measurement corrected for ionospheric effects
based on L1/L2 measured pseudoranges
pradr     pseudorange and accumulated delta range
tropocl   tropospheric correction by using a simplified model
uclock    user clock bias and drift
uercor    user earth rotation correction vector
xambig    main program generating ambiguity numbers
xionoc    main program determining iono corrections by using Klobuchar
model
xmpath    main program generating and saving the multipath pseudorange
errors
xpradr    main program generating pseudorange and accumulated delta
range
xsaerr    main program generating SA errors
xtropocl  main program generating tropospheric delay contours for a
specified location
xuclock   main program generating user clock bias and clock drift
xuercor   main program generating and plotting the magnitude of the
earth rotation correction vector for a specified longitude/
latitude grid
=====

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Determination of user's position and related functions

uspos4 position fix determination by using Bancroft's algorithm when 4 measurements are known
uposdg position fix determination by using Bancroft's algorithm when at least 4 measurements are known
uposit position fix determination by using an iterative method when at least 4 measurements are known
xpfwls main program determining position fixes using weighted least squares algorithm when the user is stationary
xuposd4 main program determining the user's position fix by using a direct method when 4 measurements are known
xuposdg main program determining the user's position fix by using a direct method when at least 4 measurements are known
xuposit main program determining the user's position fix by using an iterative method when at least 4 measurements are know

=====
RINEX 2 and SP3 data processing and position determination

svclockc computation of satellite clock correction; WGS-84 constants are used
xpsv_sp3 main program executing graphs related to SP3 satellite position for selected satellites; optional the position data for selected satellites are saved
xrinx_obs program executing the following plots related to the RINEX observation data: number of satellites tracked, repartition of satellites tracked, and for selected satellite(s) the following plots: normalized pseudorange, normalized carrier phase, normalized pseudorange minus carrier phase
xrinxn main program reads a RINEX 2 navigation message file and writes the data into four files containing the header section main information, the complete navigation section information, the reduced ephemeris and reduced almanac data
xrinxo main program reads a RINEX 2 observation message file and writes the data into two files containing the header information and the main observation data only
xsp3 main program reading a SP3 data file and writing the data into three files; one output file contains the header information, while the other two output files contain the satellites position and velocity at each time step
xsv_pos_ comparison main program computing and plotting the RSS between ECEF satellite positions based on satellite ephemeris/almanac data and the corresponding ECEF satellite position based on SP3 data
xuposr main program computing user position based on RINEX 2 navigation and observation data; no atmospheric corrections are applied
xuposra main program computing user position based on RINEX 2 navigation and observation data; iono and tropo corrections are applied
xuposrp main program computing user position based on RINEX 2 navigation and observation data; dual frequency P-code iono and tropo corrections are applied

=====
Basic RAIM/FDE functions

dhmax delta_h_max computation (used in RAIM constant alarm rate algorithm)
raimfd RAIM availability and fault detection by using the parity vector algorithm (one step implementation)
raimst RAIM availability and fault detection by using the standard (constant alarm rate) algorithm
slopemax slopemax computation (used in RAIM constant alarm rate algorithm)
xopcr main program comparing four different implementations of RAIM decision variable computation
xraimda main program determining the RAIM fault detection availability for a user selected or defined set of input data
xraimea main program determining the RAIM fault exclusion availability for a user selected or defined set of input data
xraimfd main program determining RAIM availability and fault detection by using the parity vector algorithm
xraimst main program determining RAIM availability and fault detection by using the standard (constant alarm rate) algorithm
xslope main program determining slopemax and delta_h_max for RAIM baseline standard (constant alarm rate) algorithm

Advanced RAIM/FDE functions

chi2_dof probability density function of Chi-square distribution with specified degrees of freedom

fdnt fault detection normalized thresholds

fpbias_c parity bias for Chi-square distribution with degree of freedom greater than 1

fpbias_g parity bias for Gauss distribution with one degree of freedom

gauss_1 probability density function for the normal Gaussian distribution

heLveL1 horizontal/vertical exclusion level (HEL/VEL) by using a direct conventional method

heLveL2 horizontal/vertical exclusion level (HEL/VEL) by using the parity method

heLveL3 horizontal/vertical exclusion level (HEL/VEL) by using a new efficient method

hpLvpL1 horizontal/vertical protection level (HPL/VPL) by using a direct conventional method

hpLvpL2 horizontal/vertical protection level (HPL/VPL) by using the parity method

ncchis2_k probability density function for the non-central Chi-square distribution, where k is 2 to 16 for the degree of freedom 2 to 16

grupa Q-R updating algorithm of the measurement matrix when a new clock measurement is added

sdop sub-dilution of precision (sub-DOP) quantities

swdop sub-weighted dilution of precision (sub-WDOP) quantities

xfdnt main program computing the fault detection normalized thresholds

xheLveL main program determining the horizontal/vertical exclusion level (HEL/VEL) by using three different methods

xhpLvpL main program determining the horizontal/vertical protection level (HPL/VPL) by using two different methods

xpbias main program computing the value of the parity bias for 10 degrees of freedom (dof) by using Gaussian distribution for dof = 1 and Chi-square distribution for dof>1

xgrupa main program testing the Q-R updating algorithm of the measurement matrix when a new clock measurement is added

xsdop main program determining sub-dilution of precision (sub-DOP) quantities

xslopemax_2faults main program determining slopemax for single and two-failure GPS RAIM problems

xswdop main program determining sub-weighted dilution of precision (sub-WDOP)

xxpl main program determines repartition of the number of visible satellites and the corresponding Horizontal Protection Level (HPL), Vertical Protection Level (VPL) values for a specified geographical area

GPS receiver evaluation functions

cn0_j equivalent carrier to noise power density ratio for a specified jamming level

cn0_unj unjammed carrier to noise power density ratio

fom figure of merit (FOM) determination based on ICD-059 table

pracc_cl pseudorange accuracy of Costas loop implementation when the equivalent carrier to noise power density ratio is known

prscp carrier phase smoothed pseudorange by using a first order filter

tfom setting of the time figure of merit (TFOM) value

ura setting of the user range accuracy (URA) range based on URA index of the satellite per ICD-GPS-200C table

xcn0_pr main program executing graphs related to carrier-to-noise power density ratio and pseudorange accuracy

xebudget main program determining GPS error budget

xfom main program plotting the figure of merit versus estimated position error for a specified position error range

xgpsr5s main program performing covariance analysis for the 5-state GPS receiver model (near stationary user)

xgpsr8s main program performing covariance analysis for the 8-state GPS receiver model (near constant velocity user)

xpos_error main program determining position error based on pseudorange errors; it is assumed that the user is stationary and the pseudorange errors at each time step contained a predetermined bias and a random noise

xprcp main program performing pseudorange and carrier phase data
 analysis
xprscp main program executing the pseudorange smoothing by carrier
 phase data using a first order filter
xtfom main program determining the Time Figure-Of-Merit (TFOM) when
 the estimated time error is given, and plotting the TFOM value
 versus the estimated time error
xura main program determining the User Range Accuracy (URA) range
 when the URA index is given, and plotting the URA range
 versus the URA index

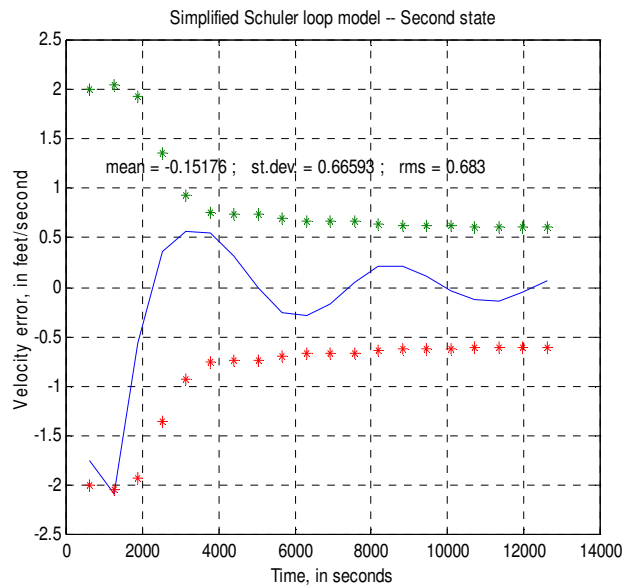
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MATLAB® KALMAN FILTERING SOFTWARE TOOLBOX

USER'S GUIDE AND REFERENCE MANUAL

-- VERSION 3 --



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Overview

M-KFTOOL (MKF)

MATLAB® KALMAN FILTERING SOFTWARE TOOLBOX

Version 3



M-KFTOOL is a library of MATLAB m-file modules and main programs used for the implementation of discrete Kalman filtering applications. M-KFTOOL enables you to simulate a specific discrete Kalman filtering application quickly and easily without the need to code and test the basic Kalman filtering algorithms.

Due to the fact that this software tool is primarily addressed to a practicing engineer, effort was made to implement the most efficient algorithms available in the technical literature. Both discrete conventional and U-D form Kalman filter formulations are included. When appropriate, more than one module performs the same mathematical computation by using different methods, so you can select the approach that best meets your specific requirements.

The MATLAB® Kalman Filtering Software Toolbox contains numerous main programs that can be modified to fit specific application needs. Once the model of the application is derived or selected, the practitioner can use the software library to implement and test the validity of the proposed GPS application.

All m-files are compatible with MATLAB version 5.0 and higher, and most of them are also compatible with previous versions and Student Edition of MATLAB.

A complete (more than 150-pages) user's guide and reference manual contains detailed documentation for each module/program included in the library. To facilitate the search for a specific function, module/program or input/output file, the manual contains a complete reference table by function as well as lists of all modules, programs, input/output files in alphabetical order. A special appendix is dedicated to a tutorial for UD implementation of discrete Kalman filtering algorithms; this tutorial is highly recommended as a starting point for someone making his/her first UD Kalman filtering application.

There are more than numerous fully explained examples (in excess of 40 pages) with input and output data, and generated plots; also a special section with discrete Kalman filtering applications is included.

The major building functions of the M-KFTOOL are divided in the following categories:

- Matrix storage and allocation

- Specialized matrix operation
- Specialized statistics functions and utilities
- Specialized plotting programs.
- General purpose and conventional Kalman filtering functions
- Specialized U-D Kalman filtering functions
- Application dependent modules
- GPS application modules

For a complete list of the modules and main programs included consult the file contents.m. Overall, there are about 100 m-files (modules and main programs), and more than 50 input and output data files.

The MATLAB source code is royalty free, i.e. the user can incorporate this software in his/her particular application but is not permitted to resell the software as is or with changes.

Here is a summary of the most significant features of GPS Toolbox software:

- all m-file modules and programs are written in MATLAB language/environment
- all m-file modules are free of input/output statements (except, of course, for those utilities that require printed output/graph, if any)
- all m-file modules are provided with detailed documentation, including scope, usage, description of parameters, remarks/notes, references, external MATLAB macros/modules used, and date of last update
- all main/test programs are provided with input/output reference data, and several detailed examples are given
- flexibility, user-friendly, and open-ended strategy. An open-ended strategy was followed which means that the user can either complement the GPS Toolbox services with his own functions or, alternatively, use GPS Toolbox functions as add-ons in conjunction with other libraries.

Computer/Software Requirements:

- IBM hardware compatible PC/386/486 or Pentium with Windows 3.1x or higher, and 640 Kbytes of RAM memory; math coprocessor for faster operation.
- MATLAB version 5.0 or higher; most m-file modules/programs are compatible with previous versions as well as the Student Edition of MATLAB
- optional, MATLAB compiler to generate high performance C code from MATLAB m-files, and additional MATLAB toolboxes.

Technical Support:

- free technical support by e-mail or fax to any registered user
- future versions and updates to keep users current with the latest M-KFTOOL developments to any registered user: free upgrades for one year since purchase

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Matrix Storage and Allocation

matc2r rectangular matrix storage transformation from one-dimensional column-wise to one-dimensional row-wise
matr2c rectangular matrix storage transformation from one-dimensional row-wise to one-dimensional column-wise
matuc2r upper triangular matrix storage transformation from one-dimensional column-wise to one-dimensional row-wise
matur2c upper triangular matrix storage transformation from one-dimensional row-wise to one-dimensional column-wise
mrlto2 rectangular matrix storage transformation from one-dimensional column-wise array to two-dimensional array
mr2to1 rectangular matrix storage transformation from two-dimensional array to one-dimensional column-wise array
msc2f symmetric matrix storage transformation from one-dimensional array column-wise - only the upper triangular part stored, to two-dimensional array
msf2c symmetric matrix storage transformation from two-dimensional array to one-dimensional array - column-wise, only the upper triangular part stored
msre reconstruct a full symmetric matrix from its stored upper triangular part; both input and output matrices are stored column-wise into one-dimensional arrays
mstr extract the upper triangular part from a symmetric matrix; both input and output matrices are stored column-wise into one-dimensional arrays
mudc2f restore full U and D matrices stored as two-dimensional arrays from its compact upper triangular part stored column-wise as one-dimensional array
mudf2c store the full U and D matrices stored as two-dimensional arrays to its compact upper triangular part stored column-wise as one-dimensional array

=====
Specialized Matrix Operations

maat post-multiplication of a rectangular matrix by its transposed matrix; the input matrix is stored column-wise, one-dimensional, and the resultant symmetric matrix is stored column-wise - only the upper triangular part
mmab multiplication of two rectangular matrices when the resultant matrix is known to be a symmetric matrix; the input matrices are stored one-dimensional, column-wise, and the resultant matrix is stored column-wise - only the upper triangular part
mmrt multiplication of a rectangular matrix and an upper triangular matrix; the rectangular matrix is stored into two-dimensional array, the upper triangular matrix is stored into one-dimensional array column-wise - only the upper triangular part, and the resultant matrix is stored into two-dimensional array
mphiu multiplication of a square matrix stored into two-dimensional array and a unit upper triangular matrix stored into one-dimensional array column-wise -- only the upper triangular part; the resultant matrix is stored into two-dimensional array

=====
Specialized Statistics Functions and Utilities

cep circular error probable (CEP) computation
convcon setting of most used conversion constants
gauss_1 probability density function of the normal Gaussian distribution
genrn generation of random numbers with normal (Gaussian) distribution
gmp1 generation of first order Gauss-Markov sequence
gmp2 generation of second order Gauss-Markov sequence
rms root mean square (RMS) of a sample
rms2 modified root mean square (modified RMS) of a sample
rss root sum square (RSS) of a three component vector sample
rssxy root sum square (RSS) of a two component vector sample

rwalk	generation of a random walk process
statup	computation of the running mean, standard deviation and root mean square for a sample
vep	vertical error probable (VEP) computation

xcepvep	main program used to compute CEP or VEP
xgenrn	main program generating random numbers with normal (Gaussian) distribution
xgmp1	main program generating first order Gauss-Markov sequence
xgmp2	main program generating second order Gauss-Markov sequence
xrwalk	main program generating random walk process sequence
xstat	main program testing the following modules: rms, rss, rssxy, and statup
xstac	main program determining mean, standard deviation, and root mean square (rms) of the elements of a specified column of the input array
=====	
Specialized Plotting Programs	
xpbar	main program plotting a bar graph for selected columns of the input array
xyp1	main program plotting the x-y graph (with manual scaling) for selected columns of the input array
xyp1s	main program plotting the x-y graph (with manual scaling) for selected columns of the input array; statistics (mean, standard deviation, and rms) is incorporated
xyp2w	main program plotting two x-y graphs (with manual scaling) for selected columns of the input array, in two windows/subplots; statistics (mean, standard deviation, and rms) is incorporated
xyp3w	main program plotting three x-y graphs (with manual scaling) for selected columns of the input array, in three windows/subplots; statistics (mean, standard deviation, and rms) is incorporated
xypc2	main program plotting a x-y graph of the difference between two data columns from different data files; statistics (mean, standard deviation, and rms) is incorporated
xypc2rss	main program plotting a x-y graph for root sum square (rss) of three specified columns from the difference of two input data files; statistics (mean, standard deviation, and rms) is incorporated
xypm	main program plotting a x-y graph (with manual scaling) for the selected columns of the input data file
xyprss	main program plotting a x-y graph (with manual scaling) for root mean square (rss) of three specified columns from an input data file; statistics (mean, standard deviation, and rms) is incorporated
xyprss2w	main program plotting two x-y graphs (with manual scaling) for root mean square (rss) of two sets of three specified columns from an input data file in two windows/subplots; statistics (mean, standard deviation, and rms) is incorporated
xypvstd	main program plotting a x-y graph (with manual scaling) for a selected column and the associated envelope (standard deviation) column from the specified input file; statistics (mean, standard deviation, and rms) is incorporated
=====	
General Purpose and Conventional Kalman Filter Functions	
gobsd	generation of observed data (measurements) for a linear time-invariant model; general form including control vector term is included
gobsd	generation of observed data (measurements) for a linear time-invariant model; the control term and process noise multiplier matrix are not included
kfcov	covariance matrix analysis for a time-invariant model by using the conventional formulation
kfcov1	covariance matrix analysis for a time-invariant model by using the conventional formulation (variant of kfcov, time propagation and measurement incorporation steps are inverted)
kfcov1a	covariance matrix analysis for a time-invariant model by using the alternate conventional formulation
mdric1	steady state solution of the discrete matrix Riccati equation; covariance matrix after measurement incorporation is determined
mdric2	steady state solution of the discrete matrix Riccati equation;

covariance matrix before measurement incorporation is determined
 measlcv covariance matrix measurement updating for one measurement by using
 conventional Kalman formulation (with symmetrization)
 measljcov covariance matrix measurement updating for one measurement by using
 Joseph stabilized Kalman formulation
 meascov covariance matrix measurement updating for all measurements by using
 classical Kalman formulation (with symmetrization)
 measjcov covariance matrix measurement updating for all measurements by using
 Joseph stabilized Kalman formulation
 mndec decorrelation of the measurement noise
 sdkf suboptimal (constant gain) discrete Kalman filter by using
 conventional formulation
 smcov determination of smoothed covariance matrix based on Rautch-Tung-
 Striebel algorithm when the model parameters are constant
 smcovps determination of smoothed covariance matrix and state based on Rautch-
 Tung-Striebel algorithm when the model parameters are constant

xgobsd main program generating the observed data (measurements) for a linear
 time-invariant model
 xgobsdr main program generating the observed data (measurements) for a
 simplified linear time-invariant model
 xkfcov main program executing the covariance analysis by using the
 conventional or alternate conventional Kalman filter formulation
 xkfcovps main program executing the discrete Kalman filter (covariance and
 state analysis) by using the conventional Kalman filter formulation
 xmdric main program computing the steady-state solution of the discrete
 matrix Riccati equation by using two different iterative methods
 xmndec main program executing the decorrelation of the measurement noise
 xsdkf main program computing the suboptimal (constant gain) discrete Kalman
 filter by using conventional formulation
 xsmcov main program executing the Rautch-Tung-Striebel smoothing for
 covariance matrix, when model parameters are constant
 xsmcovps main program executing the Rautch-Tung-Striebel smoothing for
 covariance matrix and state, when model parameters are constant

Specialized U-D Kalman Filter Functions

mcud covariance matrix determination from its U-D factors
 mrlup updating the U-D factors when a rank one matrix modification is
 applied
 mreast measurement reasonableness test for a given scalar measurement
 mudd U-D factorization of a real symmetric, positive (semi)definite matrix
 by using modified Cholesky decomposition
 mudm U-D measurement updating by using Bierman algorithm for one
 measurement, when the measurement is the input
 mudml U-D measurement updating by using Bierman algorithm for one
 measurement, when the measurement residual is the input
 mudst standard deviations (sigmas) determination from the U-D factors
 mwgs1 U-D factors determination from the un-normalized W-DW factors (used in
 the modified weighted Gram-Schmidt algorithm)
 tpudd time propagation of U-D factors by using the direct method
 tpudgs time propagation of U-D factors by using the modified weighted Gram-
 Schmidt method
 tpuds time propagation of U-D factors by using the rank one matrix updating
 method

xkfud main program implementing the discrete U-D form Kalman filter for a
 specified application. Several options related to the input/output
 data and selection of variant to be used are available
 xmuddu main program executing the decomposition and reconstruction of a real
 symmetric positive (semi)definite matrix into and from its U-D factors
 xmudm main program executing the discrete Kalman filter Bierma's U-D
 measurement updating algorithm
 xmudst main program determining sigmas (standard deviations) of a covariance
 matrix from its U-D factors
 xtpud main program executing time propagation of the U-D factors by using
 three different methods (direct method, rank one matrix updating
 method, and modified weighted Gram-Schmidt method)

=====
Application Dependent Modules
hmat measurement matrix computation
phimat transition matrix computation
qmat process noise matrix computation
rmat measurement noise matrix computation
=====

=====
GPS application modules
eleva elevation angle and the ECEF unit line-of-sight vector computation
svpalm ECEF satellite position determination based on almanac data
tgdecef geodetic to ECEF coordinates transformation
uvertv unit vertical vector for a given ECEF position vector
vecefenu ECEF (Earth Centered Earth Fixed) to ENU (East, North, Up)
transformation
wgs84con setting of most used WGS-84 constants
=====

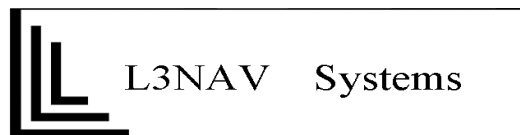
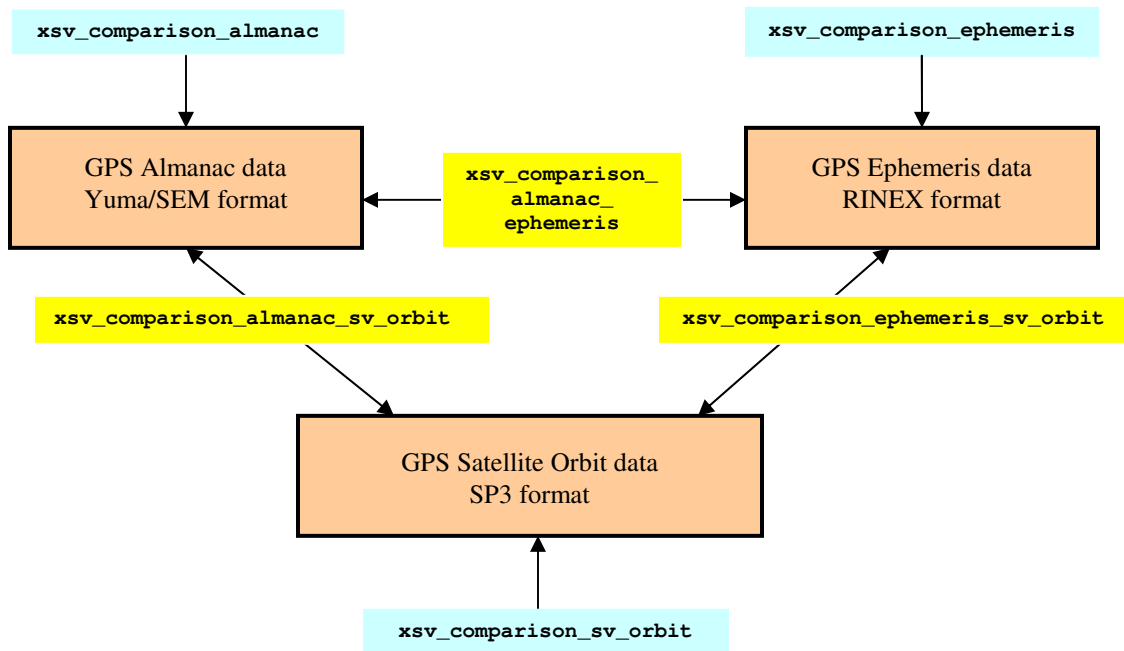
xgpsr5s main program performs covariance analysis for the 5-state GPS receiver
model (for near-stationary user)
xgpsr8s main program performing covariance analysis for the 8-state GPS
receiver model (for near-constant velocity user)
=====

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**RINEX AND SP3 (RAS) SOFTWARE TOOLBOX
FOR MATLAB®**

USER'S GUIDE AND REFERENCE MANUAL

-- VERSION 2 --



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OVERVIEW

GPS RINEX AND SP3 (RAS) SOFTWARE TOOLBOX FOR MATLAB®

Scope

The GPS RAS Toolbox library of m-file modules and main programs are intended for multipurpose use as

- Simulation tool. It can generate a realistic simulation for numerous aspects of RINEX and SP3 applications by using directly the existent main programs.
- Performance analysis tool. It can execute a variety of data analysis functions using Yuma or SEM almanac format, RINEX GPS navigation and observation files format, and SP3 GPS orbit data format.
- A starting point for user's GPS RINEX and SP3 related applications. The user can modify existent m-files to suit a specific application without the need of implementing elementary building blocks that are included in this toolbox.

General description

RAS Software Toolbox consists of various functional modules and main programs that perform mathematical and data processing services frequently encountered in GPS RINEX and SP3 related engineering calculations.

RAS Toolbox helps you solve many scientific and engineering problems related to RAS quickly and easily. This is because:

- RAS Toolbox modules are elementary building blocks, thus giving you the flexibility to combine them in many ways to fit your specific application's needs,
- these functions are input/output free, except some utilities, so they can be attached to other application's input and output modules,
- an open-ended strategy was followed which means that you can either complement the RAS Toolbox services with functions of your own or, alternatively, use RAS Toolbox modules and programs as add-ons in conjunction with other libraries,
- the software is written clearly and is well documented, thus making it easy for you to understand the algorithms and to use the code as a starting point for your own programs,
- m-file main programs have associated input data files, and therefore are ready to be used without any additional user's effort; for benchmark testing the corresponding output files are included.

Here is a summary of the most significant features of RAS Toolbox software library:

- all m-file modules and programs are written in MATLAB language/environment,
- all m-file modules are free of input/output statements (except, of course, for those utilities that require printed output/graph, if any),
- all m-file modules are provided with detailed documentation, including scope, usage, and description of parameters, remarks/notes, references, external MATLAB modules used, and date of last update.

Overall, there are more about 40 m-files (modules and main programs), and about 50 input and output data files. In addition, all main programs have test examples using default data or specified input data files.

The functions included in the GPS RAS Toolbox are divided in several categories as follows.

- General data processing for (Yuma, SEM, SP3, RINEX) data files. This category includes the reading and decoding (Yuma, SEM, SP3, RINEX) data files, and creating special data files containing reduced almanac, ephemeris and satellite position/velocity data. In addition, several general graphing main programs are including for executing plots related to almanac and ephemeris data.
- GPS satellite orbit data analysis. There are six comparison main programs that compare processed GPS satellite position and velocity data from two different sources, namely two Yuma/SEM almanacs data sets, two ephemeris data sets, two SP3 format precise orbits data sets, Yuma/SEM almanac and ephemeris data sets, comparison of Yuma/SEM almanac and SP3 format precise orbit data, and comparison of ephemeris data and SP3 format precise orbit data.
- User position determination. There are 3 user determination main programs using RINEX information decoded by general data processing programs as follows: a) determination of user position based on RINEX 2 navigation and observation data when no atmospheric corrections are applied, b) determination of user position based on RINEX 2 navigation and observation data when iono and tropo corrections are applied, c) determination of user position based on RINEX 2 navigation and observation data when dual frequency P-code iono and tropo corrections are applied.
- Utility modules. This category includes about 20 modules performing basic mathematical operations related to coordinate transformation, user position determination, setting GPS constants, iono and tropo computations, elevation and azimuth angles, satellite position and velocity computations, mathematical statistics.

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GPS RINEX and SP3 (RAS) SOFTWARE TOOLBOX -- List of functions
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General Data Processing for (Yuma, SEM, SP3, RINEX) Data Files

xread_sem main program reading SEM almanac data and creating two data files
xread_sp3 main program reading the SP3 data file and creating three data files
xread_yuma main program reading Yuma almanac data and creating two data files
xwrite_yuma main program writing the Yuma format almanac file
xrinxn main program reads a RINEX 2 navigation message data file and writes
the data into four text files
xrinxn_select main program reads a RINEX 2 navigation message data file and writes
the data into four text files; the reduced almanac and ephemeris data
files are storing the data within the selected time interval
xrinxo main program reads a RINEX 2 observation message file and writes the
data into two text files (header and observation data only)
xrinxo_select main program reads a RINEX 2 observation message file and writes the
data into two text files (header and observation data only); the
reduced observation data file is storing only the data within the
selected time interval
xrinx_obs main program executing graphs related to the satellites data provided
into the reduced observation data file generated by the program xrinxo
xsv_pv_plot_almanac main program executing graphs related to the position and velocity
when the reduced almanac data is provided
xsv_pv_plot_ephemeris main program executing graphs related to the position and velocity
when the reduced ephemeris data is provided
xsv_pv_plot_sp3 main program executing graphs related to the position and velocity
provided into a sp3 file

=====
GPS Orbit Data Analysis

xsv_comparison_almanac main program executing the satellites position/velocity comparison
when two almanacs data are provided
xsv_comparison_almanac_ephemeris main program executing the satellites position/velocity comparison
when almanac and ephemeris data are provided
xsv_comparison_almanac_sv_orbit main program executing the satellites position/velocity comparison
when almanac and sp3 orbit data are provided
xsv_comparison_ephemeris main program executing the satellites position/velocity comparison
when two ephemeris data are provided
xsv_comparison_ephemeris_sv_orbit main program executing the satellites position/velocity comparison
when ephemeris and sp3 orbit data are provided
xsv_comparison_sv_orbit main program executing the satellites position/velocity comparison
when two sp3 orbit data are provided

=====
User Position Determination

xuposr main program computing user position based on RINEX 2 navigation and
observation data; no atmospheric corrections are applied
xuposra main program computing user position based on RINEX 2 navigation and
observation data; iono and tropo corrections are applied
xuposrp main program computing user position based on RINEX 2 navigation and
observation data; dual frequency P-code iono and tropo corrections are
applied

=====
Utility Modules

convcon setting of most used conversion constants
elevaz computation of elevation and azimuth angles, ECEF unit line of sight
vector and range
geoidh computation of WGS-84 geoid height correction
gpscon setting of most used GPS constants
ionoc computation of L1 iono correction for a specified user by using the
Klobuchar model
pionoc computation of pseudorange corrected for ionospheric effects
prn2svn determination of the GPS satellite number for a specified GPS
pseudorandom number
rms computation of root mean square (RMS) of a sample
selectd selection of the different elements from a specified array

svclockc	computation of satellite clock correction
svn2prn	determination of the GPS pseudorange number for a specified GPS satellite number
svpalm	determination of ECEF satellite position based on almanac data
svpeph	determination of ECEF satellite position based on ephemeris data
svpvalm	determination of ECEF satellite position and velocity based on almanac data
svpveph	determination of ECEF satellite position and velocity based on ephemeris data
tecefgd	ECEF to geodetic coordinates (direct method)
tropocl	computation of the tropospheric correction for a specified user by using a simplified model
uposit	computation of user's position from at least four ECEF satellite positions and the corresponding pseudoranges, by using a direct method
vecefenu	transformation from ECEF to ENU frames for a given position vector and referenced latitude/longitude angles
wgs84con	setting of most used WGS-84 constants
ymd2gps	determination of (GPS week, GPS roll number, day of week) from (year, month, day)

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**COORDINATE TRANSFORMATIONS SOFTWARE TOOLBOX
FOR MATLAB®**

USER'S GUIDE AND REFERENCE MANUAL

-- VERSION 2 --

Example: UTM to geodetic coordinate transformation

```
>> xutm2gd
Do you want to save the results? (y/n) [n] -->
Enter data from keyboard? (y/n) [n] --> y
Enter UTM zone number --> 37
Enter UTM zone letter (without I and O) --> P
Enter UTM Northing --> 963944.6708176120
Enter UTM Easting --> 487429.4879707657

Latitude (rad)      Longitude (rad)
0.1522000281       0.6786838400

End of the program xutm2gd

>>
```



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OVERVIEW AND FUNCTIONAL DESCRIPTION

Consistent with our modular, structured approach to software development and implementation, CT TOOLBOX software has been designed as a system rather than as a collection of me-too functions.

This provides the ability to link your applications only with those m-file modules that are really needed, thus allowing you to reduce the size of your executable modules. This is done automatically when using CT TOOLBOX.

As an added benefit, you can also "cut-and-paste" just a few functions if this is what you need for your applications.

The m-files are separated in two categories, namely m-file modules and m-file main programs. The m-file modules are elementary blocks that are incorporating independent algorithms and most of the times do not call other elementary blocks; in general, each m-file module is used by one or more main programs and doesn't have input/output (read/write) interface. The m-file main programs are used as a high level module incorporating a specific task.

The following acronyms are used:

ECEF	Earth Centered Earth Fixed
ECI	Earth Centered Inertial
ENU	East North Up
GD	Geodetic
GNSS	Global Navigation Satellites System
INS	Inertial (Wander / North West Up)
LLW	Local Level Wander azimuth
PZ90	Parametri Zemli 1990
SGS85	Soviet Geodetic System 85
UPS	Universal Polar Stereographic
UTM	Universal Transverse Mercator
WGS72	World Geodetic System 1972
WGS84	World Geodetic System 1984

Functional Highlights

CT Software Toolbox Version 2.x consists of various functional modules that perform mathematical services frequently encountered in CT related engineering calculations.

These m-file modules and m-file main programs, referred also as functions, are written in MATLAB language / environment.

CT Toolbox helps you solve many industrial, scientific, and engineering problems related to CT quickly and easily. This is because:

- CT Toolbox modules are elementary building blocks, thus giving you the flexibility to combine them in many ways to fit your specific application's needs
- these functions are input/output free, except some utilities, so they can be attached to other application's input and output modules
- an open-ended strategy was followed which means that you can either complement the CT Toolbox services with functions of your own or, alternatively, use CT Toolbox modules and programs as add-ons in conjunction with other libraries
- software is written clearly, without gimmicks, and is well documented, thus making it easy for you to understand the algorithms and to use the code as a starting point for your own programs.
- m-file main programs have associated input data files, and therefore are ready to be used without any additional user's effort; for benchmark testing the corresponding output files are included.

The m-file modules together with main programs are intended for multipurpose use as

- a simulation tool. It can generate a realistic simulation for numerous aspects of CT applications.
- a performance analysis tool. It can execute a variety of data analysis functions.
- a starting point for user's CT related applications. The user can modify existent m-files to suit a specific application without the need to implement elementary building blocks that are implemented in this toolbox.

In addition, the effort was made to implement the most efficient algorithms available in the technical literature. When appropriate, more than one module performs the same mathematical computation by using different methods, so you can select the approach that best meets your specific requirements.

Here is a summary of the most significant features of CT Toolbox software:

- all m-file modules and programs are written in MATLAB language/environment.
- all m-file modules are free of input/output statements (except, of course, for those utilities that require printed output/graph, if any)
- all m-file modules are provided with detailed documentation, including scope, usage, and description of parameters, remarks/notes, references, external Matlab modules used, and date of last update.

Functional description

The functions included in the CT TOOLBOX are divided in several categories, each one is described in a separate paragraph. Each function contains both m-file modules and m-file main programs.

As naming conventions, the name of a main program starts with the letter “X”, and the input/output data files associated with a specific main program, when possible, have the same name except the file extensions. The convention used for the extension is as follows: “dat” for input files, “out” for output files, “mat” for input/output mat-files, and “m” for m-files.

All m-files are presented in alphabetic order in sections 4 for modules and section 5 for main programs. A complete list of functions based on subjects is included in section 2.3. Section 3 contains representative examples, including details related to the input and output files.

Overall, there are more than 50 m-files (modules and main programs), and about 30 input *.dat files and output *.out files. In addition, all main programs have test examples using default data or specified input data files.

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COORDINATE TRANSFORMATIONS SOFTWARE TOOLBOX -- List of functions
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Angle transformations

tadmsrad degrees/minutes/seconds to radians
taraddms radians to degrees/minutes/seconds
xatransf main program executing angle transformations from/to
degrees/minutes/seconds to/from radians (by selection)

=====

Point Coordinate transformations

tecefgd ECEF to geodetic coordinates (direct method)
tecefgd2 ECEF to geodetic coordinates (iterative method)
tecefgd3 ECEF to geodetic coordinates (efficient direct method)
tgdecef geodetic to ECEF coordinates
xecef2gd_comp main program executing comparison between three ECEF to geodetic
transformation methods
xptransf main program executing transformations from/to ECEF/geodetic to/from
geodetic/ECEF coordinates

=====

Matrix Coordinate transformations

mblw PS body to LLW (Local Level Wander azimuth)
mecefeci ECEF (Earth Centered Earth Fixed) to ECI (Earth Centered Inertial)
mecefenu ECEF (Earth Centered Earth Fixed) to ENU (East, North, Up)
meceflns ECEF (Earth Centered Earth Fixed) to INS (Wander / North, West, Up)
meceflw ECEF (Earth Centered Earth Fixed) to (Local Level Wander azimuth)
meciecef ECI (Earth Centered Inertial) to ECEF (Earth Centered Earth Fixed)
menuecef ENU (East, North, Up) to ECEF (Earth Centered Earth Fixed)
menullw ENU (East, North, Up) to LLW (Local Level Wander azimuth)
minsecef INS (Wander / North, West, Up) to ECEF (Earth Centered Earth Fixed)
mllwb LLW (Local Level Wander azimuth) to GPS body
mllwecef LLW (Local Level Wander azimuth) to ECEF (Earth Centered Earth Fixed)
mllwenu LLW (Local Level Wander azimuth) to ENU (East North Up)
xmtransf main program generating matrix transformations specified in the above
mentioned list (by selection)

=====

Vector Coordinate transformations

vblw GPS body to LLW (Local Level Wander Azimuth)
vecefeci ECEF (Earth Centered Earth Fixed) to ECI (Earth Centered Inertial)
vecefenu ECEF (Earth Centered Earth Fixed) to ENU (East, North, Up)
vecefgd ECEF (Earth Centered Earth Fixed) to Geodetic (latitude, longitude,
altitude) for a given position vector and a reference point
veceflns ECEF (Earth Centered Earth Fixed) to INS (Wander / North, West, Up)
veceflw ECEF (Earth Centered Earth Fixed) to LLW (Local Level Wander azimuth)
vecefp90 ECEF (Earth Centered Earth Fixed) to PZ-90 (Parametri Zemli 1990)
vecefs85 ECEF (Earth Centered Earth Fixed) to SGS-85 (Soviet Geodetic System
1985)
veciecef ECI (Earth Centered Inertial) to ECEF (Earth Centered Earth Fixed)
venuecef ENU (East, North, Up) to ECEF (Earth Centered Earth Fixed)
venugd ENU (East, North, Up) to Geodetic (latitude, longitude, altitude) for
a given position vector and a reference point
venullw ENU (East, North, Up) to LLW (Local Level Wander azimuth)
vgdecef Geodetic (latitude, longitude, altitude) to ECEF (Earth Centered Earth
Fixed), for a given position vector specified by the external points
in geodetic coordinates
vgdenu Geodetic (latitude, longitude, altitude) to ENU (East, North, Up) for
a given position vector specified by the external points in geodetic
coordinates
vinsecef INS (Wander / North, West, Up) to ECEF (Earth Centered Earth Fixed)
vllwb LLW (Local Level Wander azimuth) to GPS body
vllwecef LLW (Local Level Wander azimuth) to ECEF (Earth Centered Earth Fixed)
vllwenu LLW (Local Level Wander azimuth) to ENU (East North Up)
vp90ecef PZ-90 (Parametri Zemli 1990) to ECEF (Earth Centered Earth Fixed)
vs85ecef SGS-85 (Soviet Geodetic System 1985) to ECEF (Earth Centered Earth
Fixed)
xvtransf main program executing vector transformations specified in the above
mentioned list (by selection)

=====

UTM and UPS coordinate transformations

int2ltr conversion of integers 1 to 24 into letters A to Z except I and O
ltr2int conversion of letters A to Z except I and O into integers 1 to 24
xgd2ups main program performing geodetic to UPS transformation
xgd2utm main program performing geodetic to UTM transformation
xups2gd main program performing UPS to geodetic transformation
xutm2gd main program performing UTM to geodetic transformation

=====

GNSS related constants and conversion factors

convcon most used conversion constants
gpscon most used GPS constants
pz90con most used PZ-90 constants
sgs85con most used SGS-85 constants
wgs72con most used WGS-72 constants

wgs84con most used WGS-84 constants
xcon main program displaying constants specified in macros convcon,
 gpscon, pz90con, sgs85con, wgs72con, and wgs84con

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