Brief Descriptions and Implementation of the "batch_unit" Source Code—A Computer Program for Parameter Optimization of Initial Abstraction, Constant-Loss Unit Hydrograph Watershed Models

A study concerning initial abstraction, constant-loss unit hydrograph models for applicable watersheds in Texas was performed by the U.S. Geological Survey (USGS) in 2006 (Asquith and others, 2007). An objective of that study was to investigate different rainfall loss functions, given *a priori* unit hydrograph parameters (time-to-peak and shape factor). Further, the calculation of optimal rainfall loss-function parameters by constrained minimization of modeled and simulated data residuals was desired. A suite of in-house software, collectively called "batch_unit", was developed to assist in these objectives. This document is provided as a limited description of the batch_unit source code.

batch_unit can be run in two different modes of operation: (1) rainfall loss-model parameter optimization (inverse modeling), and (2) forward unit hydrograph watershed modeling using pre-defined input rainfall loss-model parameters. Scripts are supplied that illustrate both modes of operation. The complete example datasets used by these are also supplied, as well as the output text and PDF graphics files that they create.

All source code files of the batch_unit software were written using the integrated computing environment MatLab (The MathWorks, 2006), and the software must consequently be run in that environment. Certain functions of the MatLab Statistics Toolbox (version 5.2) were also used, requiring the installation of this toolbox library for full functionality. The remainder of this document provides brief descriptions of the individual modules used in the batch_unit software and an example of their implementation. It is not in any way intended as a user's manual for the software, nor does it attempt to explain any of the mathematical or computational algorithms used therein. Further documentation of the programming details may be found as comment text within the source code files themselves.

Source Code Files and Descriptions

The following source code files are part of the batch_unit software package.

EXAMPLE_INVERSE_BATCH.m

This script illustrates the inverse-modeling mode of the batch_unit software. Multiple rainfall-loss optimization models are run using example input datasets and run parameters.

EXAMPLE_FORWARD_BATCH.m
This script illustrates the forward-modeling mode of the batch_unit software. Example input datasets and run parameters are used.

batch_unit.m
This function performs multiple unit hydrograph precipitation loss-function optimizations in batch for a given set of input parameters.

bRcT_diff.m
This function differentiates an input x- and y-dataset using a "backwards in y" and "centered in x" method.

calc_K.m
This function calculates the shape parameter K used in the gamma unit hydrograph.

calc_obj.m
This function calculates the outflow of the unit hydrograph model. The results are compared to the observed values, and an objective function is applied to evaluate model performance. The objective function value obtained is minimized to optimize the rainfall-loss model parameters.

calc_P.m
This function generates synthetic rainfall time-series.

calc_Q.m
This function computes the runoff hydrograph for a storm given input unit hydrograph parameters and excess rainfall.

calc_qp.m
This function calculates the peak discharge given the time-to-peak and the gamma unit hydrograph shape parameter, K.

calc_Tp.m
This function calculates the time-to-peak given channel slope, channel length, and watershed development status.

calc_U.m
This function generates the gamma unit hydrograph given the peak discharge, time-to-peak, and shape parameter.

calc_vol.m
This function calculates the accumulated runoff volume as a function of time given by a hydrograph time-series. A mid-point integration method is used.

cfs2inhr.m
This function converts values in cubic feet per second to inches per hour.

do_run.m
This function runs a single unit hydrograph optimization run.

echo_run_info.m
This function echoes all run parameters for a batch_unit run to the screen.

find_n_peaks.m
This function finds the number of local minima or maxima in a given input vector.

fminsearchbnd.m
This function finds the minimum of a multivariable function with bounded constraints. It is used to minimize the objective function and find optimal rainfall-loss parameters.

get_c0.m
This function reads an input comma-separated text file and returns an array of station identification numbers and loss parameters used by batch_unit in the forward modeling mode.

get_files.m
This function finds all hydrograph and hyetograph data files in the input directory and all its subdirectories. Corresponding hydrograph and hyetograph files are paired and only those that have watershed characteristics defined are output.

get_staid.m
This function extracts a station identification number from a file name.

get_Tunit.m
This function finds the time needed for the gamma unit hydrograph to diminish to the specified fraction of the peak.

get_ws_char.m
This function reads and returns selected watershed characteristics from an input file.

inhr2cfs.m
This function converts values in inches per hour to cubic feet per second.

parse_input.m
This function parses multiple input arguments given to batch_unit and assigns the values to a data structure.

plot_obj.m
This function plots the objective function of an optimized model run in parameter space. It is only used in the "debug" mode of operation for diagnosing inversion convergence.

plot_out.m
This function creates a plot for a batch_unit run and saves it as an individual PDF file in the output directory.

precip_loss.m
This function applies a loss function to a total rainfall time-series to and returns the effective rainfall.

regress_mbr.m
This function takes input vectors x and y, performs a least-squares regression, and returns the slope, y-intercept, and r-squared from the resulting linear fit.

run_model.m
This function runs a unit hydrograph model.

trim_precip.m
This function takes an interpolated accumulated rainfall time-series, finds the total volume, and trims specified fractions of volume from the beginning and end.

unaccum.m
This function converts an accumulated time-series into an ordinary (instantaneous) one.

write_out.m
This function writes model results to the output text file.

zeropad.m
This function converts an input integer to a character string and pads it with leading zeros to a specified width.

Running the batch_unit Software

To run the batch_unit software scripts, the MatLab computing environment with the Statistics Toolbox must be installed on the host machine (The MathWorks, 2006). Compatibility issues may occur using versions other than MatLab version 7.2 (release R2006a) and Statistics Toolbox version 5.2 (release R2006a). The script files "EXAMPLE_FORWARD_BATCH.m" and "EXAMPLE_INVERSE_BATCH.m" were prepared to illustrate the implementations of batch_unit using the supplied input database directory "EXAMPLE_INPUT_DATA".

Before running the software, the zipped source archive "batch_unit_source.zip" must be copied and decompressed to a location on the host machine, and the MatLab computing environment must be launched.

Running an Example Forward Unit Hydrograph Model

Within MatLab, navigate to the directory to which the "batch_unit_source.zip" archive was copied and uncompressed. At the command line prompt, type "`EXAMPLE_FORWARD_BATCH`". This will launch the forward modeling example run, and progress should be echoed to the console window. Upon completion, all run output will be written to a newly created directory. This output is also supplied with the batch_unit package in the "EXAMPLE_OUTPUT\FORWARD_MODEL" directory.

Further explanation of the forward model run can be obtained by examining the "EXAMPLE_FORWARD_BATCH.m" script.

Running an Example Inverse Unit Hydrograph Model

Within MatLab, navigate to the directory to which the "batch_unit_source.zip" archive was copied and uncompressed. At the command line prompt, type "`EXAMPLE_INVERSE_BATCH`". This will launch the inverse modeling example run, and progress should be echoed to the console window. "EXAMPLE_INVERSE_BATCH.m" is an example of running several batch inversions in succession using varying run parameters. Upon completion, all run output will be written to several newly created directories, one for each of the individual inversion batches in the script. This output is also supplied with the batch_unit package in the "EXAMPLE_OUTPUT\INVERSE_MODEL" directory.

Further explanation of the inverse model run can be obtained by examining the "EXAMPLE_INVERSE_BATCH.m" script.

References

Asquith, W.H., and Roussel, M.C., 2007, An Initial Abstraction, Constant-Loss Model for Unit Hydrograph Modeling for Applicable Watersheds in Texas: U.S. Geological Survey Scientific Investigations Report 2007–5243, 82 p.

The MathWorks, 2006, MATLAB version 7.2.0.232 (R2006a): Natick, Mass.