Gait Analysis (Instruction Manual)

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1. **What is Gait Analysis?**

Gait Analysis is a graphical interface to the VU-HMS Gait Toolbox, which is a collection of MATLAB programs that analyze the data that have been recorded with a so called *MoveMonitor* from McRoberts (see www.mcroberts.nl). The MoveMonitior is based on miniaturized body-fixed inertial sensors that allow ambulatory measurements of body acceleration.

Conceptually, Gait Analysis does not do much by itself. It is merely intended to offer a user-friendly interface to the VU-HMS Gait Toolbox for new users, offering to change parameters in a user-friendly way, (re)run the analysis and inspect the outcome. Intermediate results will also be saved to MATLAB files, allowing the end-user to implement his/her own analyses.

2. Installation

Currently, Gait Analysis is available for Window, Mac and Linux users. An installation file of the latest stable version for Window can be downloaded from:

https://www.dropbox.com/s/baviqambuayraqs/GaitAnalysis_AppInstaller_web.exe?dl=0.

A beta version of the newest release, if available, can be downloaded from:

https://www.dropbox.com/s/ta79vopc9tutfyv/GaitAnalysis_AppInstaller_beta_web.exe?dl=0.

Sample data to try it out can be downloaded from:

https://www.dropbox.com/s/hww8aexd5fo84w6/Gait%20Analysis%20Data.zip?dl=0.

Windows will probably warn that the installer might not be safe. Just discard all warnings, save the file and run it. At first run, the installer will download and install the appropriate MATLAB Runtime system, which is needed to run Gait Analysis. This runtime system is pretty large (around 2GB), so downloading and installing will take some time. When done, it will install Gait Analysis in the folder "Vrije Universiteit Amsterdam" under "Program Files" on your system disc. Optionally, you can check `<Create desktop icon>` during the installation for easy access.

Linux and Max users may request an installation file by e-mailing kaass@fbw.vu.nl. For Mac users there is also a download link (experimental):

https://www.dropbox.com/s/26o4yn9bdvuo2bj/GaitAnalysis_AppInstaller_web.app.zip?dl=0

Just like on Windows, at first install the MATLAB Runtime system (around 2GB) will be downloaded and installed, which will take some time.

3. Running the application

Launching the application can be very slow, particularly when the MATLAB Runtime system is stored on a conventional hard disc rather than a solid-state disc. You will probably see a small splash screen, which will disappear after a short while. Thereafter, it's possible that you don't see anything happening for minutes; just be patient and eventually you are likely to see the following screen:
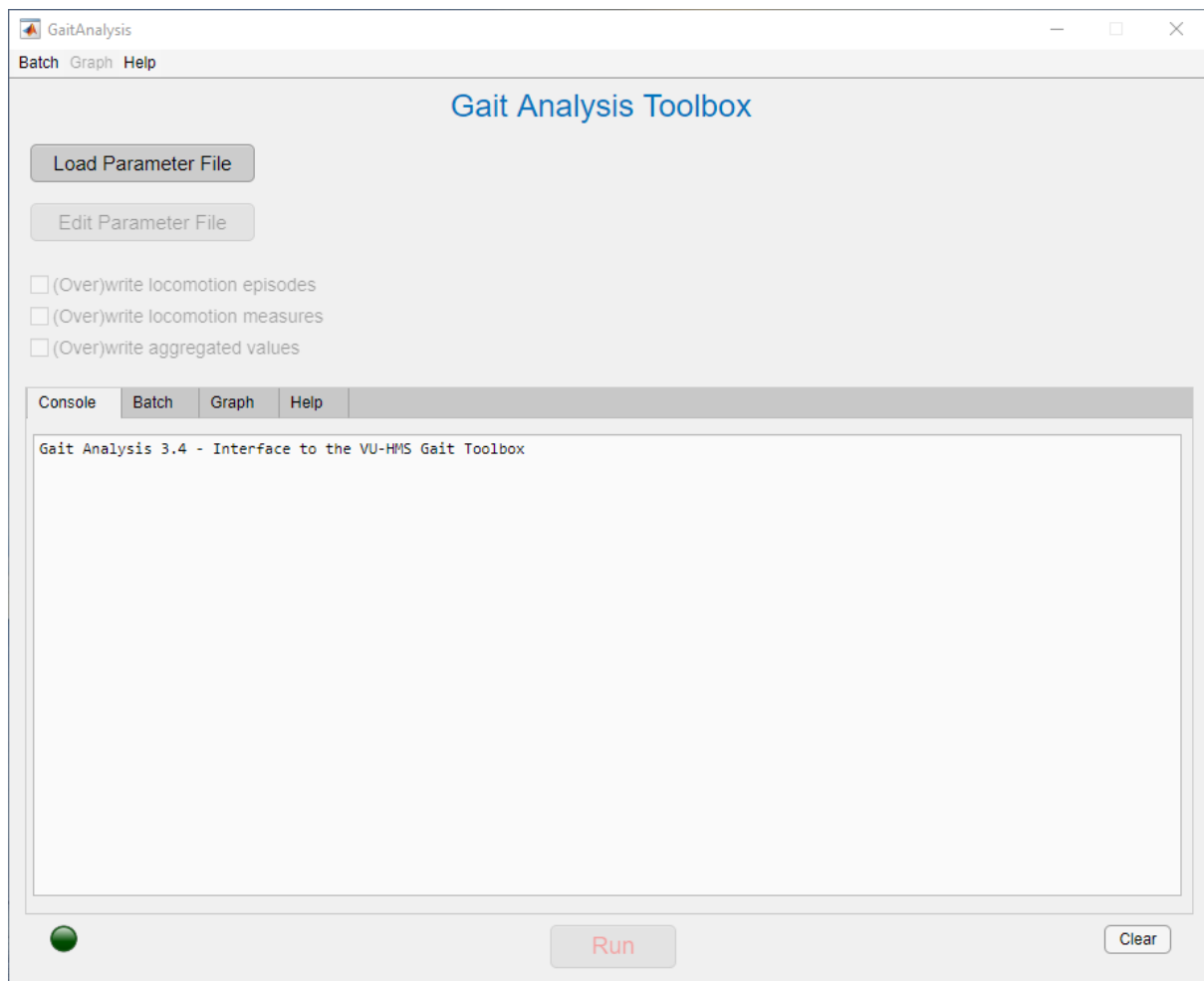
To use the downloaded sample data, extract the contents of the zip-file to `D:\`.[1] It will create a folder named `Gait Analysis Data/Test1`, containing three files: a raw measurement file `TestData1.omx`, a classification file `TestData1.csv`, and a parameter file `GaitParams1.txt`. The raw measurement file is obtained from the MoveMonitor and the classification file can be generated by McRoberts.

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[1] You may choose an alternative location, but then you will need to change the data folders in the parameter file later on.

Now press the `<Load Parameter File>` button and find the `GaitParams1.txt` file (at first use, it may take a while before the file chooser opens). If the sample data is stored in `D:\Gait Analysis Data`, the screen will change to:
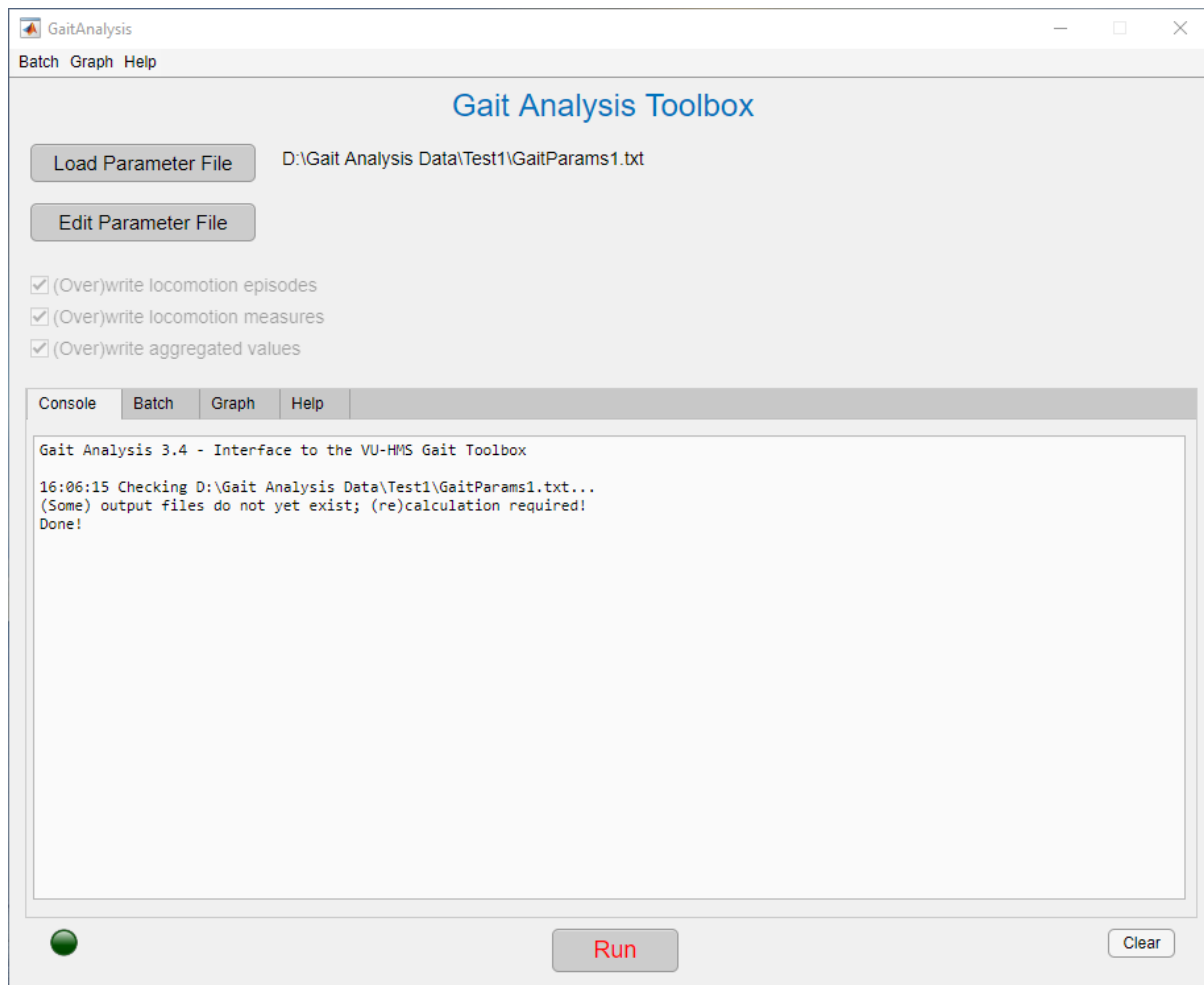
You can press `<RUN>` right away or take a look at the parameter file first (and optionally edit it).[2] If you press `<Edit Parameter File>`, an attempt is made to open Notepad. If you prefer (or if opening Notepad fails) you may also open the parameter file with your favorite text editor. Before pressing `<RUN>`, do not forget to save the file if any changes have been made.

If your data is saved elsewhere, e.g., on drive `C`, the `<RUN>` button is disabled and you will see the following error:

```
Classification file (D:\Gait Analysis Data\Test1\TestData1.csv) as specified in the
parameter file does not exist.
```

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[2] A sample parameter file can also be viewed by pressing `<Help | Show example parameters>`. An overview is also presented in Appendix A.

You will have to edit the parameter file and adjust the folder name of both the classification file and the raw measurement file (e.g., change `D:\` to `C:\` in this example).

Because no output files have ever been generated for this data set, the check boxes are checked and disabled. Pressing `<RUN>` will result in the extraction of locomotion episodes and the calculation of a vast number of variables. This will take quite some time for a large data set and eventually result in the following output (you will have to use the scrollbar to see the latest messages)[3]:

```
Parameters that will be used:
  Classification file: D:/Gait Analysis Data/Test1/TestData1.csv
  Raw measurement file: D:/Gait Analysis Data/Test1/TestData1.omx
  Leg length: 0.925
  Epoch length: 10
  Cutoff frequency: 0.50
  Seconds to skip from start of measurement: 21600
  Percentiles: [10 50 90]
  Output file locomotion episodes: D:/Gait Analysis Data/Test1/TestData1_GA_Episodes.mat
  Output file locomotion measures: D:/Gait Analysis Data/Test1/TestData1_GA_Measures.mat
  Output file aggregated values:   D:/Gait Analysis Data/Test1/TestData1_GA_Aggregated.mat
  Output file requested results:   D:/Gait Analysis Data/Test1/TestData1_GA_Results.mat
  Output file physical activities: D:/Gait Analysis Data/Test1/TestData1_GA_Activity.txt
  Get physical activity from classification: yes
  Minimal sensor wear time: 18 hours per day
  Minimum number of valid days for activities: 2
  Minimum number of valid days for lying: 3

Collecting physical activity from classification file...

Total wear time: 138.74 out of 168.01 hours
Valid days: 4 out of 8

Mean activities per day:
        Number of strides:  1512
         Walking duration:  00:39:50 (n=239)
        Standing duration:  02:45:23 (n=617)
         Sitting duration:  07:17:28 (n=102)
          Lying duration:  12:27:48 (n=10)
         Cycling duration:  00:00:00 (n=0)
   Stair walking duration:  00:00:09 (n=1)
    Unclassified duration:  00:17:26 (n=404)

Mean transitions per day (total = 1375):
         to  walking  standing  sitting  lying  cycling  stair_walking  unclassified
       from  -----------------------------------------------------------------------
       walking      0      216       22      0       0            1             1
      standing    217        0       32      5       0            0           368
       sitting     21       38        0      4       0            0            35
         lying      0        1        8      0       0            0             0
       cycling      0        0        0      0       0            0             0
  stair_walking      1        0        0      0       0            0             0
   unclassified      1      359       45      0       0            0             0

Detailed information can be found in D:/Gait Analysis Data/Test1/TestData1_GA_Activity.txt.
```

---

[3] Note that from version 3.1 onwards, physical activity information will be extracted from the classification file first. This will only take a minute and can be suppressed by including the line

```
    Get physical activity from classification = no
```

in the parameter file.

```
Extracting locomotion episodes (may take a while)...
Extracting   393/393.
Time to extract locomotion episodes = 23.83 seconds.

Calculating locomotion measures (may take a while)...
Completed episodes =   393/393.
Time to calculate locomotion measures = 192.44 seconds.
Collect aggregated values...

General measures:
             WalkingSpeed:  0.598  0.932  1.110
             StrideLength:  0.805  1.115  1.232
         SampleEntropy_VT:  0.133  0.174  0.247
         SampleEntropy_ML:  0.146  0.193  0.242
         SampleEntropy_AP:  0.194  0.239  0.338
       StrideRegularity_VT:  0.180  0.451  0.724
                   RMS_ML:  1.419  1.632  1.977
       IndexHarmonicity_ML:  0.529  0.863  0.964
        PowerAtStepFreq_AP:  0.268  0.430  0.602
   GaitQualityCompositeScore: -1.831 -0.882  0.284

Bimodal Fit Walking Speed:
                 Ashman_D:  4.016
              PeakDensity:  0.373  0.627
                PeakSpeed:  0.641  1.017

Percentile of Preferred Walking Speed: 86.73

Above measures can also be found in D:/Gait Analysis Data/Test1/TestData1_GA_Results.txt.

All done!
```

From version 3.2 onwards, the above measures will also be calculated for individual test days; these measures can be found in the above-mentioned file `*_GA_Results.txt`.

You could press `<RUN>` again with unchecked check boxes to see that all the previously generated files will be loaded from disc now. Changing parameters may result in checkboxes being checked and disabled again, because the current output files will no longer match the new parameter settings (see `<Help | Show example parameters>` for a brief explanation). If you correct the settings, the check boxes will be re-enabled, but you will have to uncheck them manually if desired.

## 4. Using batch tables

### 4.1 Adding, updating and deleting parameter files

To process more than one data set without manual intervention, for example overnights, parameter files can be added to a batch table. In the menu bar `<Batch>` you will find several options, as shown in the screenshot below. Because the currently loaded parameter file is free of errors and not yet art of the current batch table (which is still empty), it may be added by pressing `<Batch|Add>`.
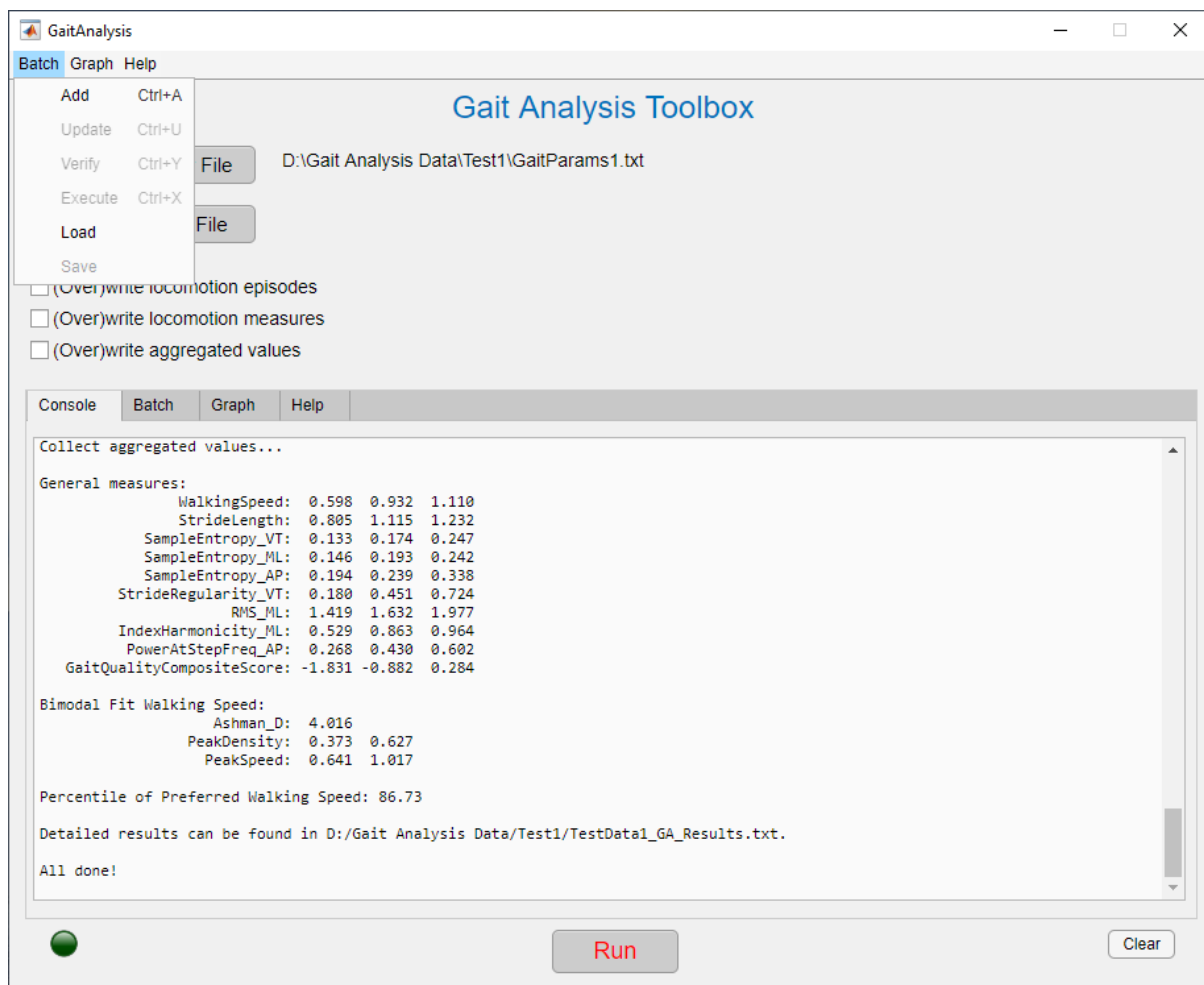
The `Batch` tab will be automatically selected, and it will show a batch table with the added parameter file as the only item (see screenshot below). Because the currently loaded parameter file is now part of the batch, the option `<Batch|Add>` is no longer available, but `<Batch|Update>` is. You may change one or more of the three checkboxes at the top of the screen and press `<Batch|Update>` to reflect these change(s); the right most three checkboxes in the batch table cannot be edited directly!
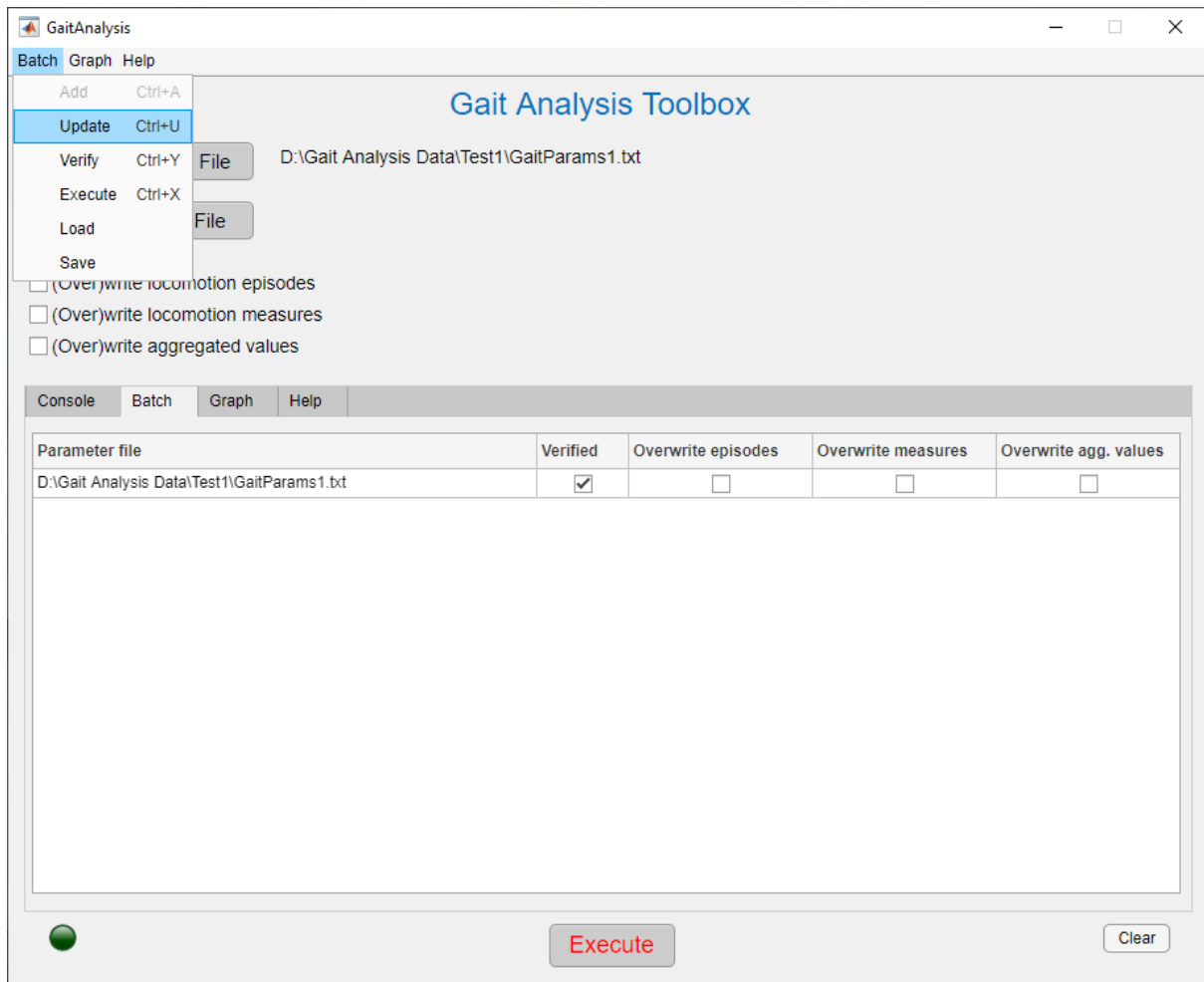
The left most checkbox, named <Verified>, may be unchecked if you want this item to be skipped during the next execution of the batch. To permanently delete an item, click on it with the right mouse button (see below) or press <Clear> at the bottom right to empty the entire batch table.
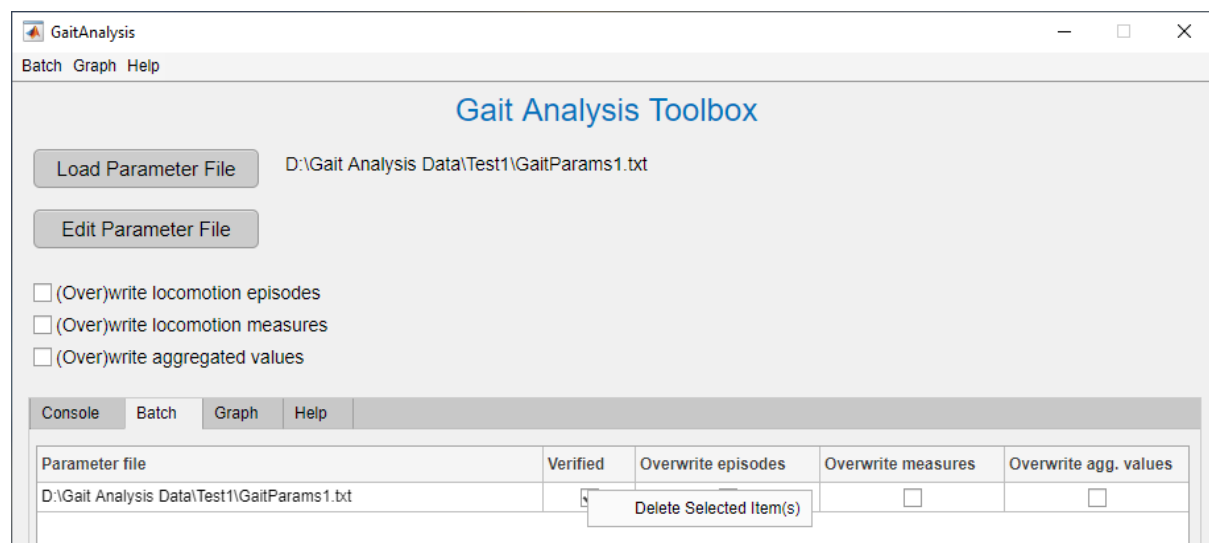
4.2 Loading and saving a batch

A batch table can be saved to disc by pressing `<Batch|Save>`. You will be asked to enter a filename. If you already have a batch file, locate it and press `<yes>` if you are asked to replace the file. You will not lose the previous contents; the current batch table will just be added (a single batch file is a container that can store up to 1000 batch tables). If you do not have a batch file yet, select a folder (e.g., `D:\Gait Analysis Data`) and type a name. It is recommended to use `Gait Batch`, optionally with a string attached (e.g., `GaitBatch_myname`), so it can be found easily later on. After you have selected a batch file, you are asked to type a name for the batch table (e.g., `10-50-90 percentiles`) .The current date and time will automatically be appended to this name.

To load a batch file, press `<Batch|Save>` and select a batch file. A list of available batch tables will appear to choose from, like
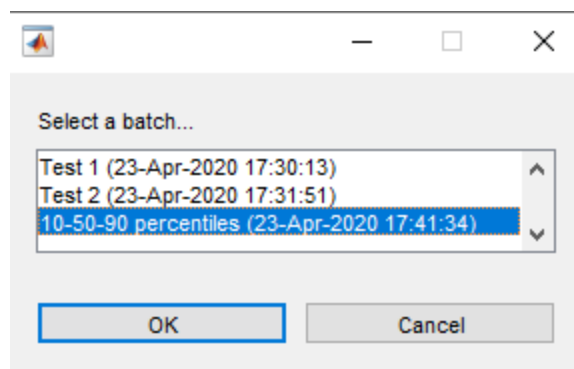
After a choice is made, you will be asked whether you would like to merge the contents with the current batch table, or just replace it. In either case, several messages may appear in the `Console` tab. Since the loaded batch table may be quite old, parameter settings may have changed, data files may no longer exist, and so on. If important messages are available, either the appropriate tab (e.g., `Console` or `Batch`) is automatically selected, or the little lamp in the lower left corner will light up to let you now that important information is available in another tab (the title of the corresponding tab will be marked blue as well). In the screenshot below you will see the possible result of loading a batch table.
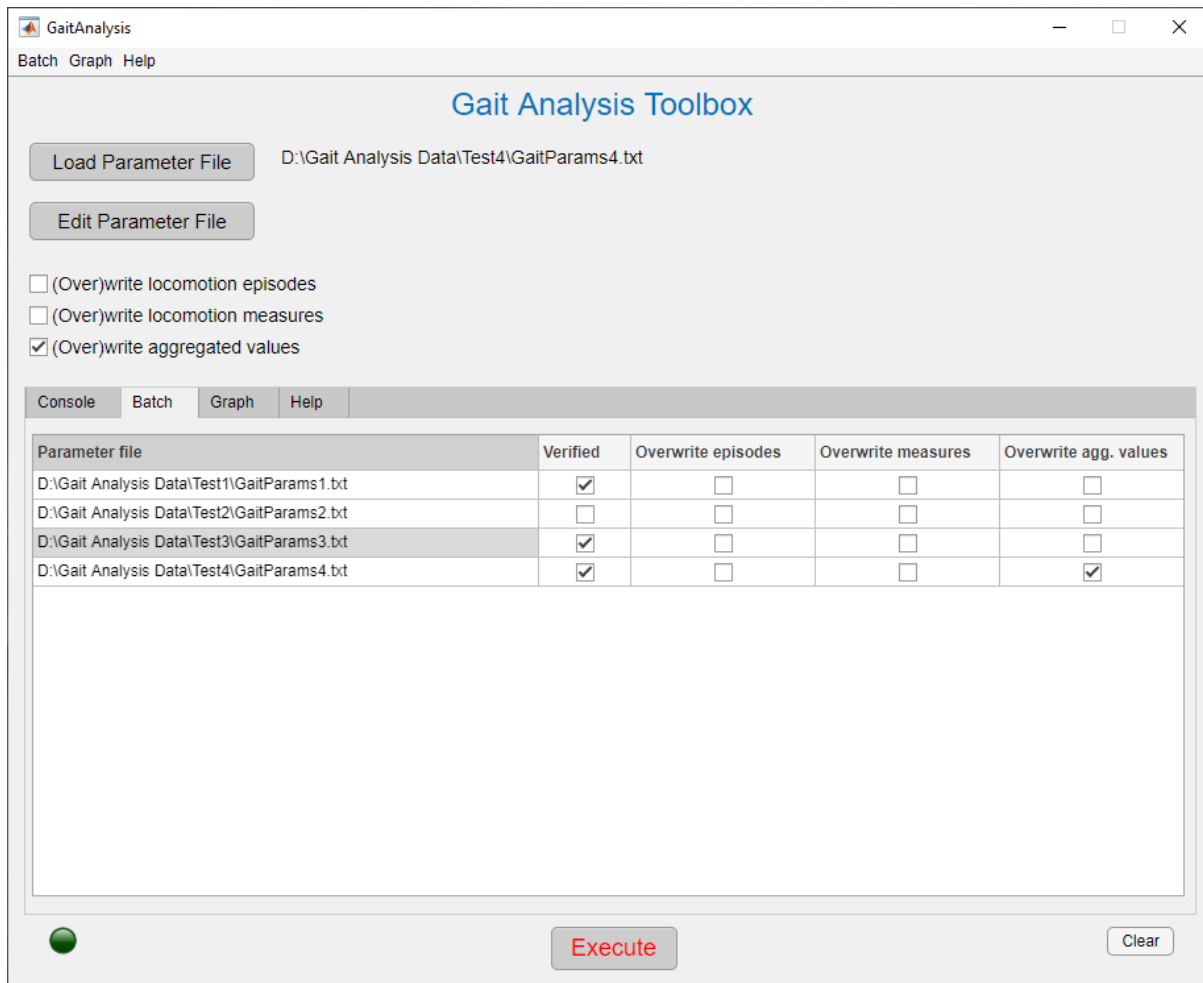
If we switch to the `Console` tab, we see the following messages:

```
Gait Analysis 3.4 - Interface to the VU-HMS Gait Toolbox

14:31:00 Batch 'V3 (16-Feb-2022 14:30:24)' loaded.
Verifying batch items...
Parameter file 'D:\Gait Analysis Data\Test2\GaitParams2.txt' not verified in current batch table, but seems okay!
You may tick the check box in the batch table if desired.
For parameter file 'D:\Gait Analysis Data\Test4\GaitParams4.txt', some files do not need to be overwritten!
You may reload this parameter file and update the batch table if desired.
Done verifying!
```

The first message tells us that we may check the `<Verified>` checkbox for the second item (otherwise it will be skipped during the execution of the batch). The second message tells us that aggregated values of the last item are already on disc. If you don't want them to be recalculated, load the corresponding parameter file and press `<Batch|Update>`. Likewise, you may load another parameter file, check one or more of the checkboxes at the top, and press `<Batch|Update>` to enforce recalculation of episodes, measures or aggregated values.

Besides these two rather harmless messages, there are quite a lot of more serious messages that can show up after loading a batch table. For example, the entire parameter file may no longer exist, the data or classification files referenced in the parameter file cannot be found anymore, or some settings in the parameter file may have been changed. There will be a notification (and possible solution) for each of these errors.

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4.3 Executing a batch

A batch can be executed by either pressing the `<Execute>` button or through the menu option `<Batch|Execute>`. If any errors are found, you will be notified and asked to verify the batch with `<Batch|Verify>` to solve them. Executing the batch table listed in the previous screenshot may result in the following output (note that although the batch table contains four items, only three will be processed since the `<Verified>` checkbox of the second item is not ticked):
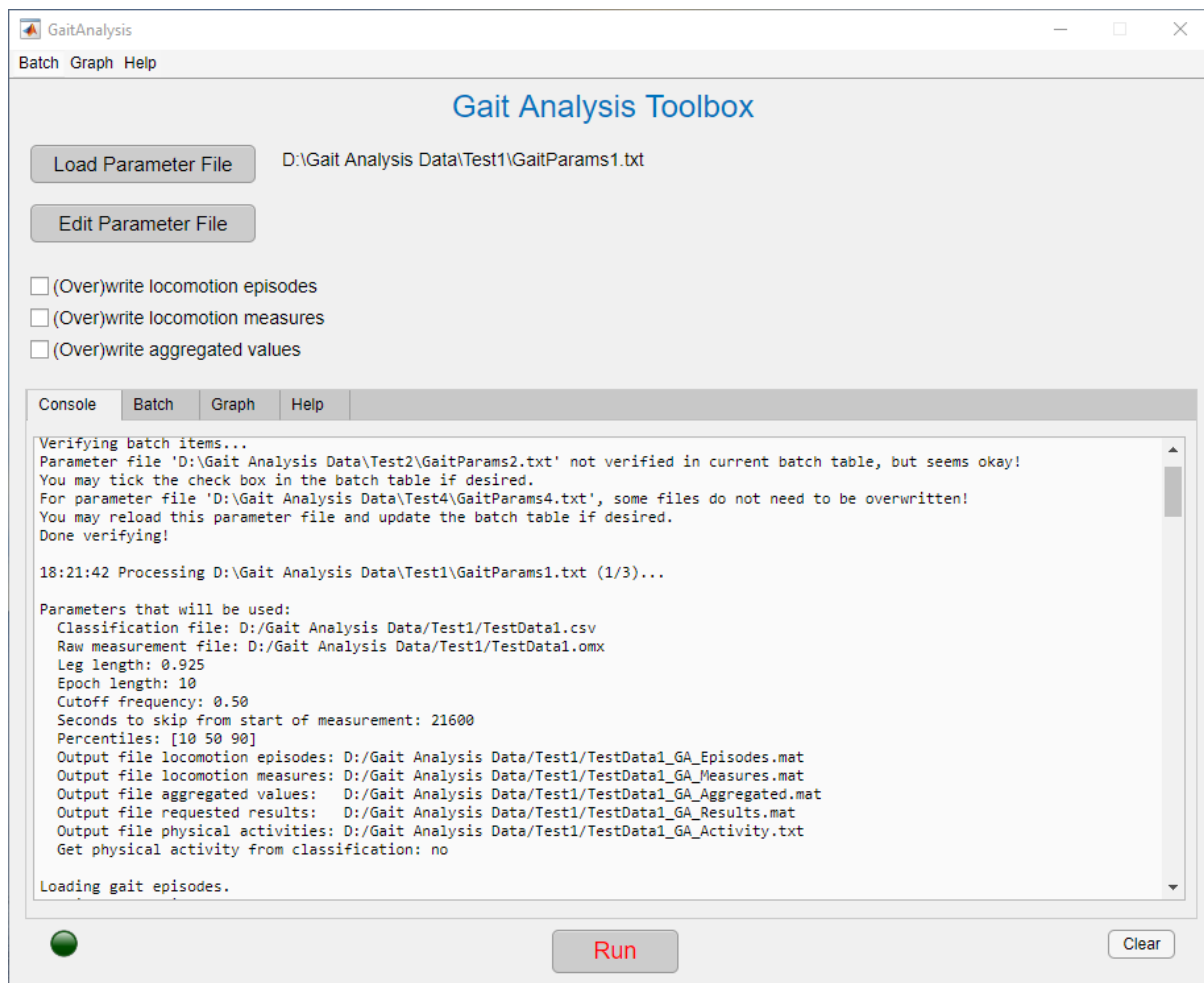

Note that during the execution of a batch, all buttons and menus are disabled. If data sets are processed for the first time (requiring the extraction of the locomotion episodes as well as the calculation of all measures and aggregated values), this can really take a long time! Prior to version 2.0, this process could not be interrupted. From version 2.0 and onwards, there is a `<Cancel>` button to abort the process as soon as possible (e.g., before the start of a new episode).

5. Graphs

Depending on the aggregated values that were requested in the parameter file (e.g., 'Walking Speed = Yes'), some plots are available after the file has successfully been processed through the Graph tab. Use the Graph menu to switch between different figures, as shown below:
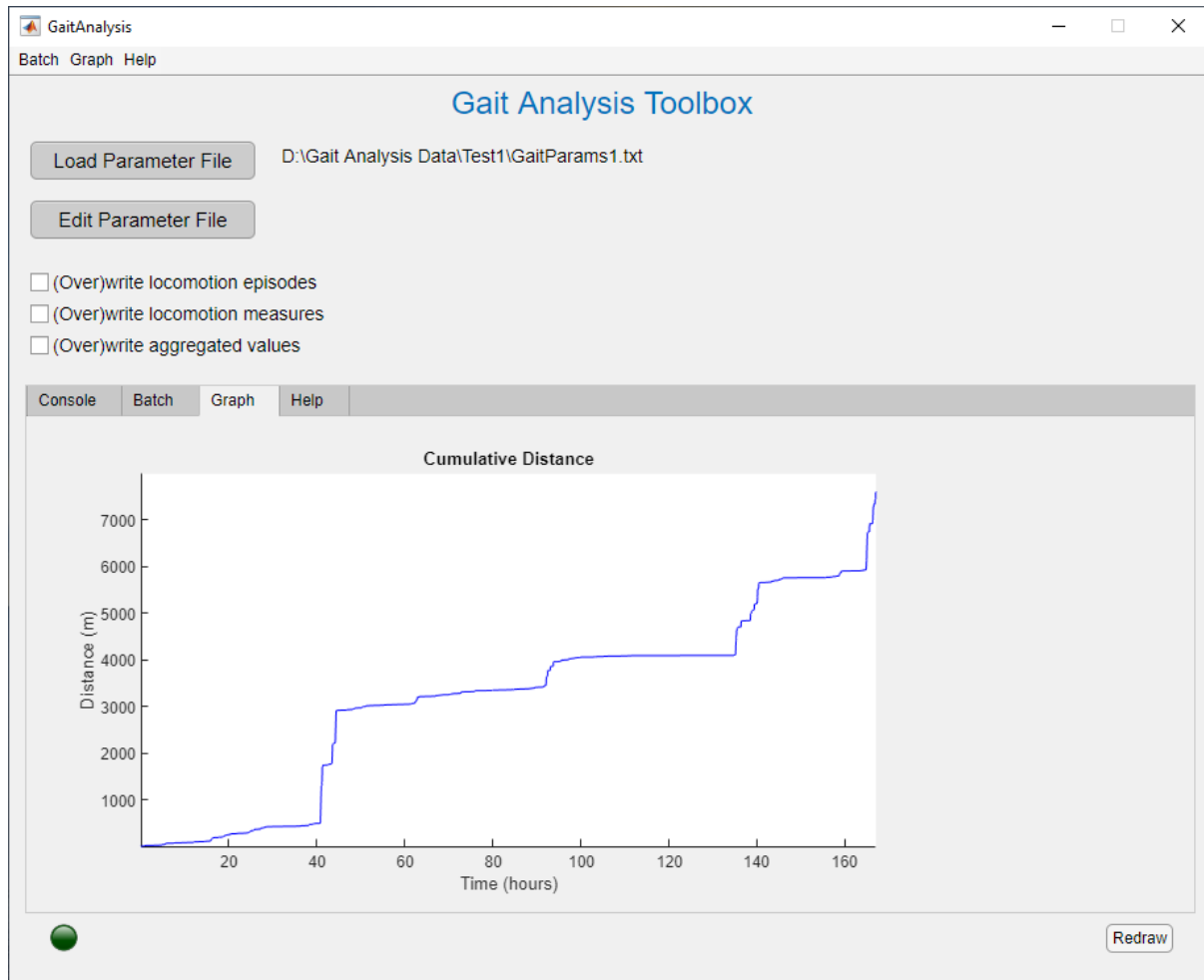
The data concerning individual parameters like Walking Speed and Stride Duration can be viewed as a whole, or on a per day or per hour basis by changing the View Mode:
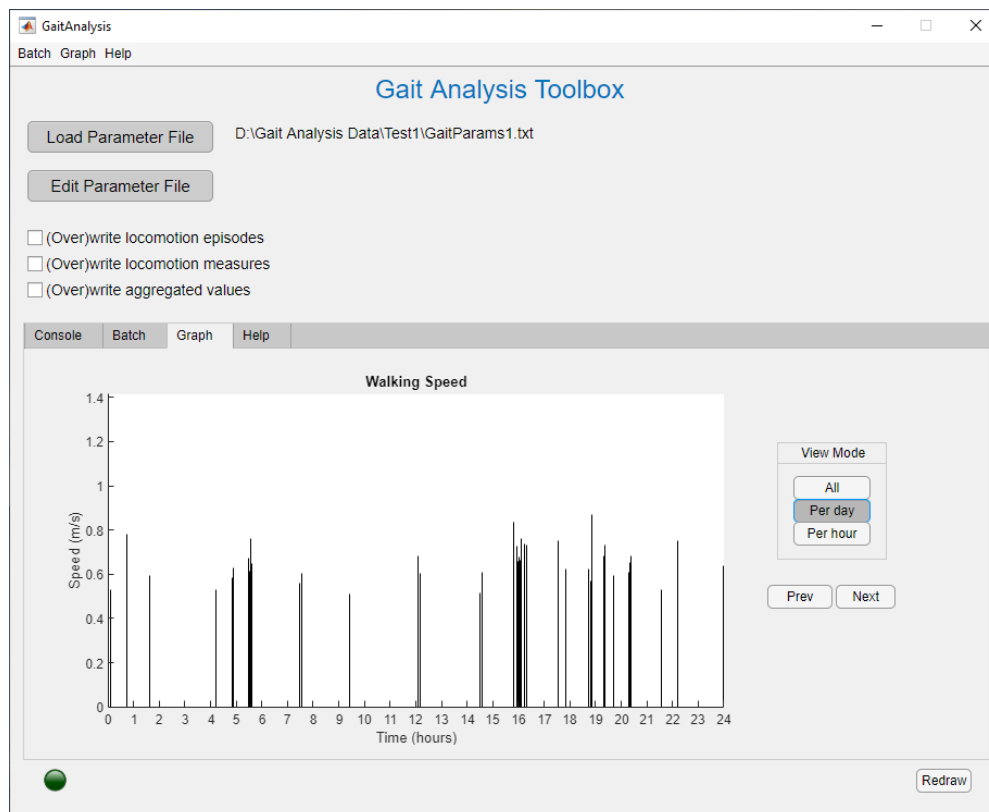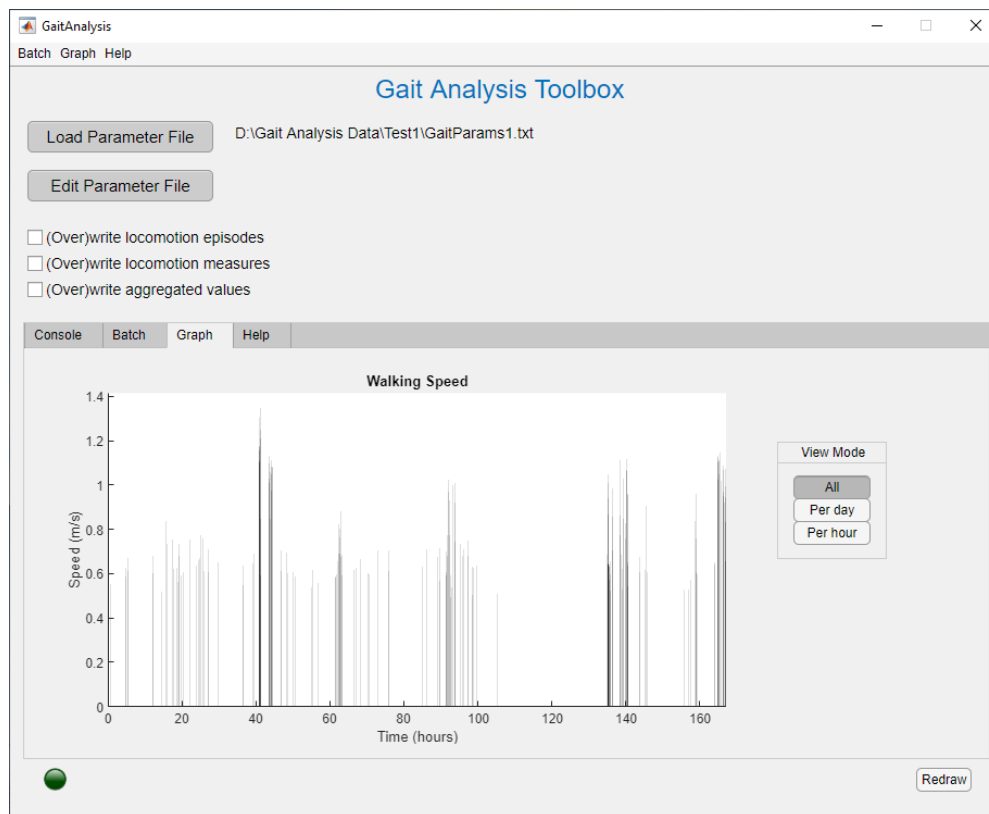
There also is an option to plot a Histogram and Density Function for the Walking Speed. Based on the number of walking episodes, an appropriate interval size is chosen (but this can be overruled):
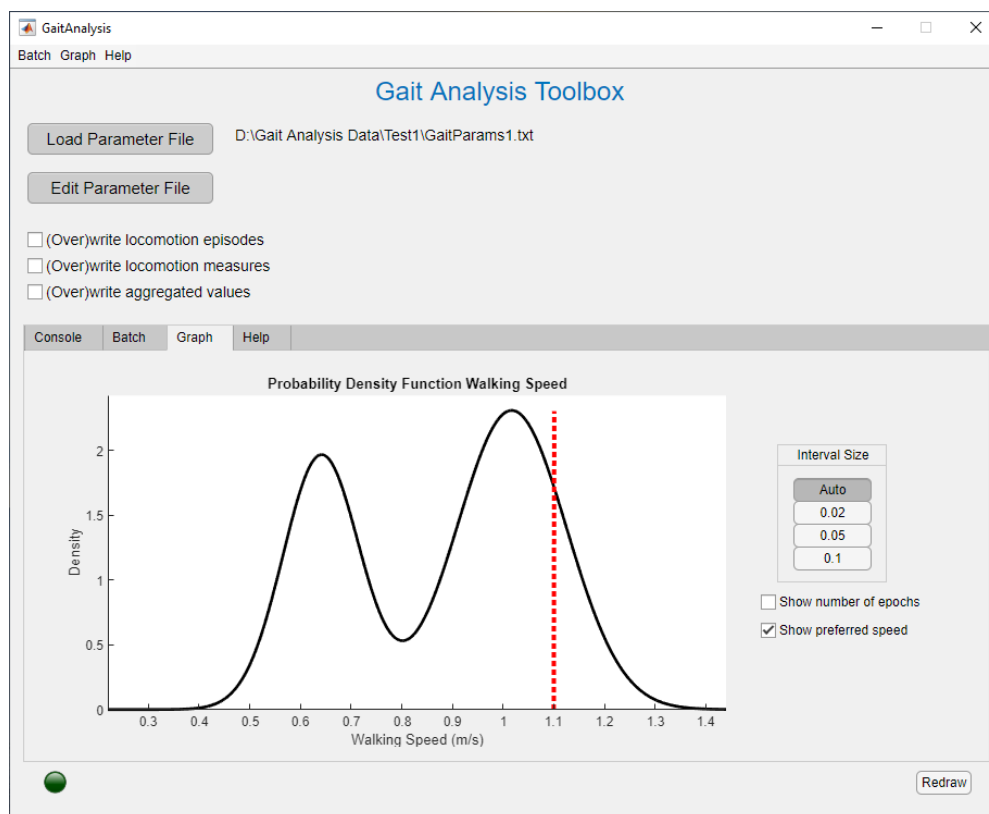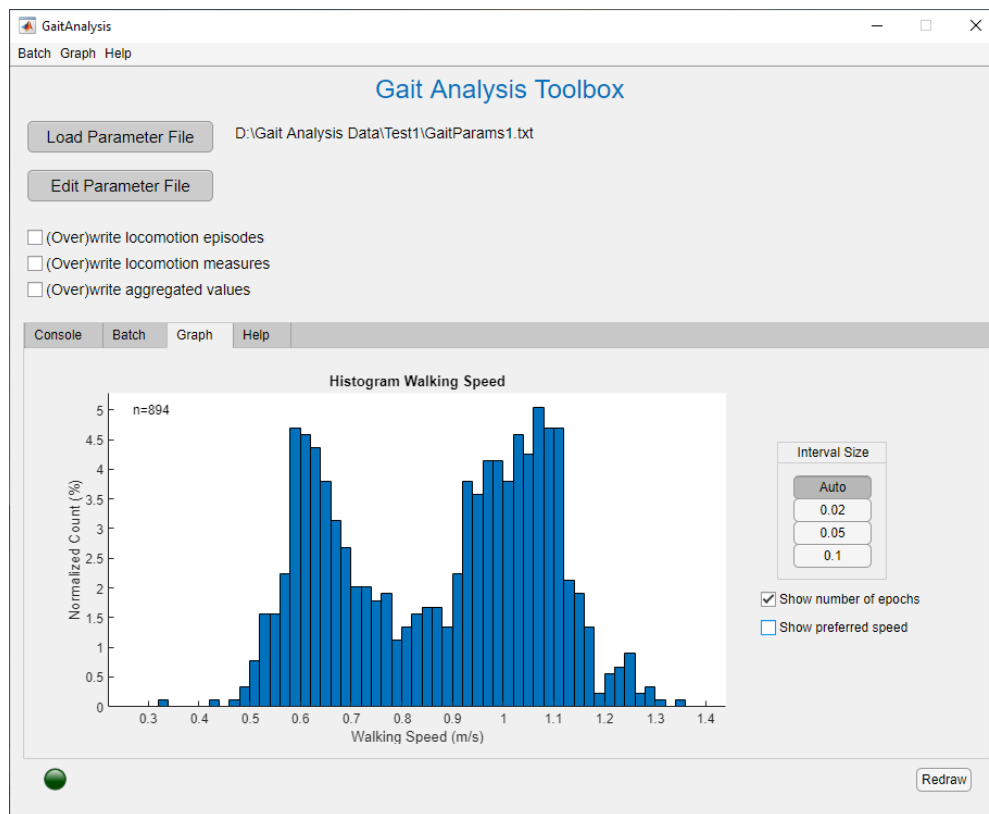
Both plots can be combined in a plot that is called the Distribution of Daily Life Walking Speed. The option to show the preferred speed (indicated by the red dotted line) is only available if the line `Preferred Walking Speed = x` (where x is the preferred speed in m/s) is present in the parameter file. [4]

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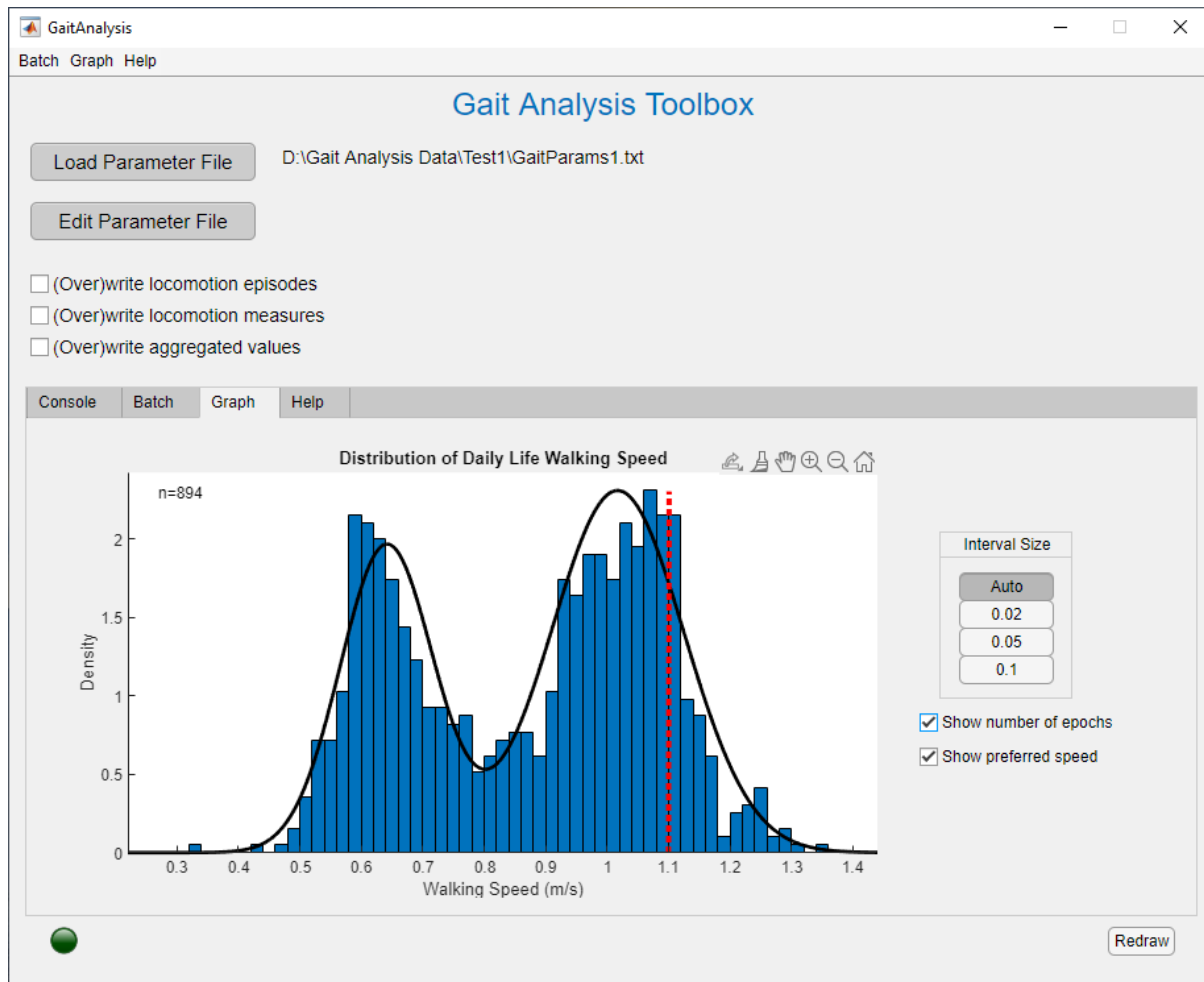
[4] This line will also make sure that the percentile corresponding to the preferred speed is included in the list of aggregated values.

6. Log files

In section 3 on page 6, a list of output files is shown. From version 3.3 onwards, you will find an additional file named `D:/Gait Analysis Data/Test1/TestData1_GA_Log.txt`. It contains detailed log messages collected during the analysis. Among other things, it may be used to look up the settings that were used during the analysis. It may also come in handy if something goes wrong; by inspecting the errors and warnings, you might get a clue to the problem. Log messages are always appended, so you will build an history of all previous analyses until you decide to clear (part of) the log file yourself.

A few log messages are generated before the output files are created. These are appended to the file `log.txt` in either the users' home directory (in case a stand-alone executable version of the application is used) or the current working directory (in case the application is run in the MATLAB environment).

Appendix A. Sample parameter file

```
% Parameter settings:
    Classification file  = *.csv  % mandatory!
    Raw measurement file = *.omx  % mandatory!


    Leg length**         = 0.925  % mandatory!
    Epoch length***      = 10     % defaults to 10


    Cutoff frequency     = 0.5    % defaults to 0.5; used in high pass Butterworth
                                  % filter to counteract integration drift


    Hours to skip at start of measurement* = 6  % defaults to 0; hours may be
                                                % replaced by seconds or minutes


    Percentiles* = [10 50 90]     % defaults to [20 50 80]

    % *** changing requires recalculation of locomotion episodes, locomotion
    %     measures, and aggregated values
    %  ** changing requires recalculation of locomotion measures and
    %     aggregated values
    %   * changing requires recalculation of aggregated values


    Get physical activity from classification = yes % defaults to yes
    Min. sensor wear time per day             = 18 % consider 12 hours if
                                                   % sensors are not worn at night
    Min. number of valid days for activities  = 2  % minimum number of days with
                                                   % sufficient wear time required
                                                   % for showing activity info
    Min. number of valid days for lying       = 3  % idem for showing "lying" info


% Measures that can be requested through the parameter file:
    Walking Speed              = yes
    Stride Length              = yes
    Stride Regularity*         = yes
    Sample Entropy*            = yes
    RMS*                       = yes
    Index Harmonicity*         = yes
    Power At Step Freq*        = yes
    Gait Quality Composite Score = yes
    Bimodal Fit Walking Speed**  = yes
    Preferred Walking Speed      = 0.96 % corresponding percentile will be reported
    % *Add VT, ML, or AP to request individual directions.
    % **Does not always converge to the exact same solution.

% Output format of the above measures (in addition to text and MATLAB; available
% from version 3.4.1 onwards):
    Save to JSON               = yes  % default = yes
    Save to SPSS               = yes  % default = no
```