User manual to Acti4(a) program

The Acti4 program is a Matlab script for analysis of data recorded by ActiGraph (AG) model GT3Xplus, Axivity model AX3, ActivPAL or Sens accelerometers and an ActiHeart (AH) or a Bodyguard2 (Firstbeat) monitor for heart rate recording. The input data are typically recorded by a set of accelerometer units attached to the thigh, hip, arm and trunk during several days (e.g. 7 days) and AH data for 3-4 days. The output data includes analysis of activity type (lying, sitting, standing, walking etc.), arm and trunk inclination and heart rate load for selected periods of work and leisure.

Acti4 handles data from up to 4 accelerometer units: thigh, hip, arm and trunk. The thigh position must always be selected and the analysis will classify the activities into sitting, standing still, moving, walking, running, walking stairs, cycling and rowing. If the trunk or hip position is added, the analysis will also include lying (it is not possible to differentiate between sitting and lying only from the thigh accelerometer). In general, the trunk position is preferable compared to the hip position. For the trunk it is optional to use the back (T1/T2 level) or the front (sternum). Furthermore, the trunk and arm accelerometer enables analysis of trunk and arm inclinations. Optionally, an accelerometer at the leg below the calf can be included for detection of kneeling position.

Installation of Acti4
Acti4 is available for a Windows 64 bit system.
Open http://www.mathworks.se/products/compiler/mcr/, download and run the Matlab Compiler Runtime Release R2013b for Windows 64-bit. You are now ready the run Acti4_64.exe. Windows must be using a period ".‌" as the decimal separator. Date and time format must be "dd-mm-yyyy" and "HH:MM:SS", respectively. Also, Excel must be available on the computer.

Accelerometer initialization/download procedure

Actigraph
All accelerometers must be initialized at the same time, and the sample rate must be 30 Hz.
File names should be selected according to the following convention:
The first 5 (there must be 5 and first character should not be 0) characters are the reference number of the subject. The next sequence of characters should identify the position of the AG and one of the following options must be used (lower/upper case is optional):
- thigh position: thigh, leg, femur, (ben, lår)
- hip position: hip, crist, (hofte)
- arm position: arm, delto
- trunk position: back, front, sternum, chest, (ryg, bryst)

For the trunk it is optional to position the accelerometer at the back or the front; however, the file name must indicate the actual position selected.
It is convenient to include the start date in the file name when the accelerometer data are downloaded. Do not include personal names in the file name.

Raw data (gt3x files) created by the ActiLife software version 5 can be read directly by the Acti4 programme. Data files by ActiLife version 6 are compressed and must be converted to an internal file type 'act4' to be used for Acti4. This conversion includes two steps, first the raw data files (gt3x) are converted to text files (csv) by ActiLife (File>Import/Export>GT3X->CSV). Then the created csv files are converted to act4 files using the Acti4 menu entry 'Convert ActiGraph CSV- files' (delete csv files afterwards).

Axivity

For the AX3 units it is not possible directly to use the above file naming system. When initializing AX3 accelerometers the measurement is assigned a 10 digit recording session ID, and the file name of the raw data (cwa file) then consists of the serial number of the AX3 unit and the 10 digit session ID. A utility is included in Acti4 for conversion of these cwa data files to the same internal act4 type as used for the Actigraph units. To use this procedure, precisely 5 digits must be used for session assignment (subject ID similar to Actigraph measurement). When initializing the AX3 accelerometers use a sample frequency of 25 Hz (100 Hz also works, but the raw data files become unnecessarily large and take longer time to read); the item 'Unpacked data' must not be checked. Maximum range is ±8g.

ActivPAL
ActivPAL recordings with a sample frequency of 20 or 40 Hz, 10 bits resolution and dynamic range +/-4G (aP4 mode) are accepted by Acti4. When setting up an ActivPAL recording, an ID must be specified consisting of precisely 5 digits (first digit >0). When downloading the data, it is optional to enter a download ID, but if done, the text must not contain any hyphens ("-"). Recordings must be exported to compressed or uncompressed csv-format by the ActiPAL analysis software before the data can be used by Acti4.

Sens
Raw data must be exported from the Sens server by selecting the binary format and files must be renamed so the first 5 characters specify the ID number and characters 7 to 14 must specify the serial number of the Sens unit.

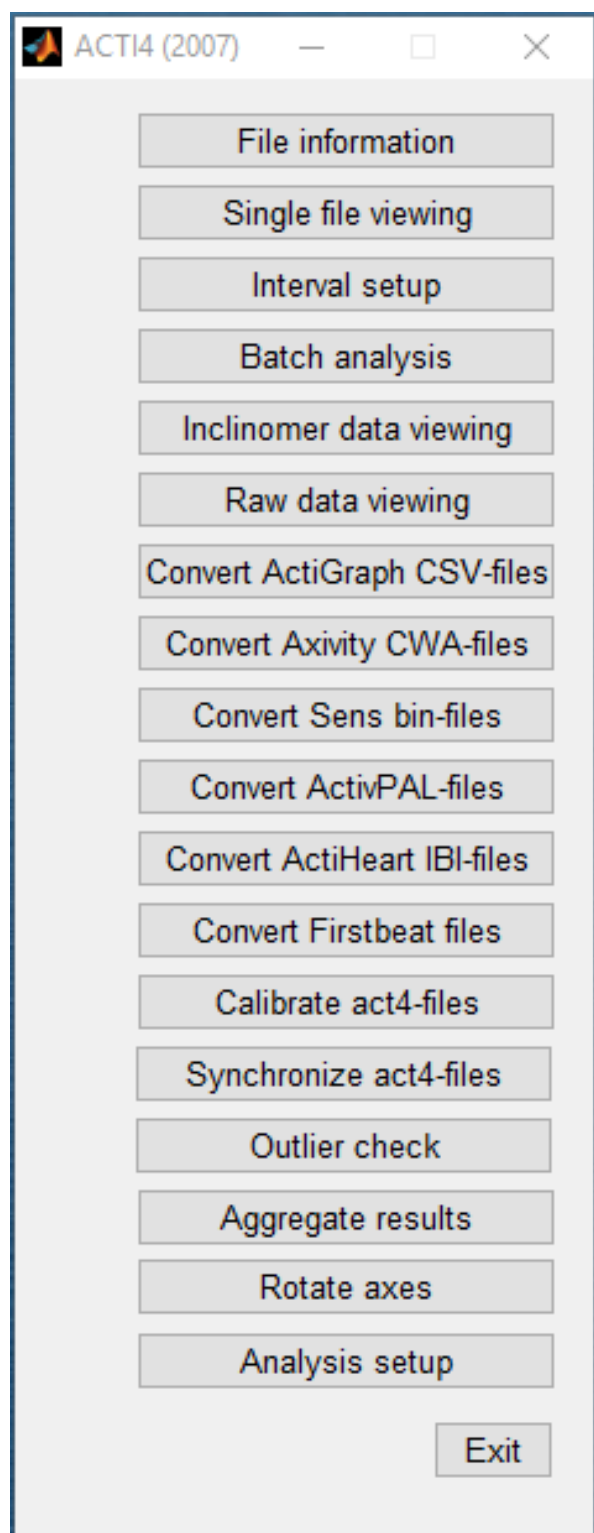*Reference- and synchronization measurement*
A reference measurement is a measurement for which the subject holds a normal upright standing position (arms downwards) for approximately 10 seconds, which enables Acti4 to calculate the angles between the axis of the accelerometer and actual body part. Reference recordings are optional (from version 1807A). A procedure including reference measurement could be to make a reference measurement at the start and end of the measurement period, and once a day for measurement during several days (and if an accelerometer has been repositioned after a not-worn period). If no reference measurements are included, Acti4 will estimate reference angles from periods of walk.
Since the accelerometer timers may deviate 1-2 seconds per day, it is recommended to make a synchronization measurement by the end of the measurement period before downloading the data (for measurements during several days with more than one accelerometer per subject). This can be done by positioning the accelerometer units on a stick (with double-side tape) oriented in the same direction, and making a sudden turning movement around the axis of the stick. Before and after this sudden movement the accelerometer assembly should lie still for a few minutes.

Orientation of accelerometers at the body surface
Acti4 can handle data from ActiGraph, Axivity, ActivPAL and Sens accelerometers. By the attachment of accelerometers to the body surface, the serial number side of the accelerometer should be inwards and the X-axis downwards for the ActiGraph, Axivity and ActivPAL accelerometers. For the Sens accelerometer the side with the serial number should the outwards. However, if the orientation deviates from this, it can be shifted during import of data (inward/outward, upward/downward or both).

Main menu of Acti4

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from ActiGraph, Axivity, ActivPAL and Sens accelerometers

File information

Use this menu entry to get a list of file names, start/stop/download times and serial numbers for selected AG recordings. Select a directory containing AG data files and select one or more files, for example:
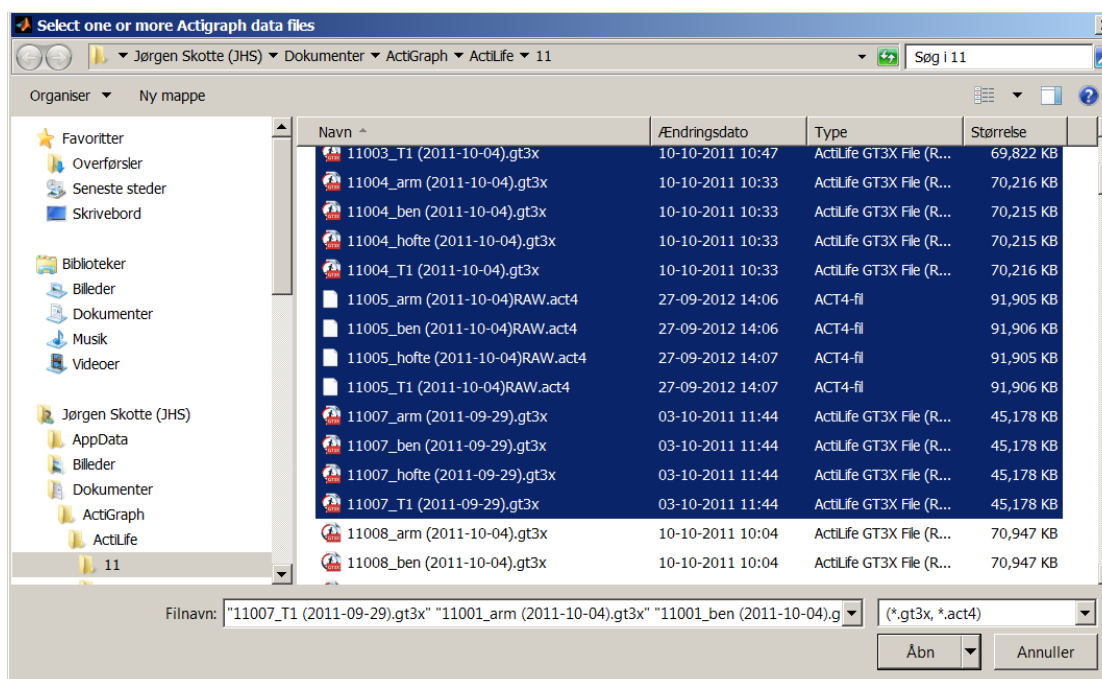
And the following table appears:

	Filename	Type	Start	Stop	Down	D:HH:MM:SS	Hz	Serial No.
1	11001_T1 (2011-10-04)	gt3x	04-Oct-2011 11:50:00	10-Oct-2011 11:30:00	10-Oct-2011 10:11:48	5:22:21:40	30	NEO1C13110039
2	11001_arm (2011-10-04)	gt3x	04-Oct-2011 11:50:00	10-Oct-2011 11:30:00	10-Oct-2011 10:11:49	5:22:21:40	30	NEO1C13110038
3	11001_ben (2011-10-04)	gt3x	04-Oct-2011 11:50:00	10-Oct-2011 11:30:00	10-Oct-2011 10:11:50	5:22:21:40	30	NEO1C13110036
4	11001_hofte (2011-10-04)	gt3x	04-Oct-2011 11:50:00	10-Oct-2011 11:30:00	10-Oct-2011 10:11:51	5:22:21:40	30	NEO1C13110037
5	11002_T1 (2011-10-04)	gt3x	04-Oct-2011 08:03:00	10-Oct-2011 10:00:00	10-Oct-2011 10:14:28	6:01:56:59	30	NEO1C13110007
6	11002_arm (2011-10-04)	gt3x	04-Oct-2011 08:03:00	10-Oct-2011 10:00:00	10-Oct-2011 10:14:31	6:01:56:59	30	NEO1C13110006
7	11002_ben (2011-10-04)	gt3x	04-Oct-2011 08:03:00	10-Oct-2011 10:00:00	10-Oct-2011 10:14:29	6:01:56:59	30	NEO1C13110004
8	11002_hofte (2011-10-04)	gt3x	04-Oct-2011 08:03:00	10-Oct-2011 10:00:00	10-Oct-2011 10:14:58	6:01:56:58	30	NEO1C13110005
9	11003_T1 (2011-10-04)	gt3x	04-Oct-2011 09:50:00	10-Oct-2011 10:00:00	10-Oct-2011 10:47:31	6:00:09:59	30	NEO1C13110024
10	11003_arm (2011-10-04)	gt3x	04-Oct-2011 09:50:00	10-Oct-2011 10:00:00	10-Oct-2011 10:47:33	6:00:09:59	30	NEO1C13110023
11	11003_ben (2011-10-04)	gt3x	04-Oct-2011 09:50:00	10-Oct-2011 10:00:00	10-Oct-2011 10:47:34	6:00:09:59	30	NEO1C13110021
12	11003_hofte (2011-10-04)	gt3x	04-Oct-2011 09:50:00	10-Oct-2011 10:00:00	10-Oct-2011 10:47:32	6:00:09:58	30	NEO1C13110022
13	11004_T1 (2011-10-04)	gt3x	04-Oct-2011 09:01:00	10-Oct-2011 10:00:00	10-Oct-2011 10:33:36	6:00:58:58	30	NEO1C13110016
14	11004_arm (2011-10-04)	gt3x	04-Oct-2011 09:01:00	10-Oct-2011 10:00:00	10-Oct-2011 10:33:38	6:00:58:59	30	NEO1C13110015
15	11004_ben (2011-10-04)	gt3x	04-Oct-2011 09:01:00	10-Oct-2011 10:00:00	10-Oct-2011 10:33:37	6:00:58:56	30	NEO1C13110013
16	11004_hofte (2011-10-04)	gt3x	04-Oct-2011 09:01:00	10-Oct-2011 10:00:00	10-Oct-2011 10:33:35	6:00:58:56	30	NEO1C13110014
17	11005_T1 (2011-10-04)RAW	act4	04-Oct-2011 08:46:00		10-Oct-2011 10:26:15	6:01:13:57	30	NEO1C13110012
18	11005_arm (2011-10-04)RAW	act4	04-Oct-2011 08:46:00		10-Oct-2011 10:26:11	6:01:13:56	30	NEO1C13110011
19	11005_ben (2011-10-04)RAW	act4	04-Oct-2011 08:46:00		10-Oct-2011 10:26:13	6:01:13:57	30	NEO1C13110009
20	11005_hofte (2011-10-04)RAW	act4	04-Oct-2011 08:46:00		10-Oct-2011 10:26:13	6:01:13:56	30	NEO1C13110010
21	11007_T1 (2011-09-29)	gt3x	29-Sep-2011 12:57:00	03-Oct-2011 10:00:00	03-Oct-2011 11:44:36	3:21:02:59	30	NEO1C13110543
22	11007_arm (2011-09-29)	gt3x	29-Sep-2011 12:57:00	03-Oct-2011 10:00:00	03-Oct-2011 11:44:37	3:21:02:59	30	NEO1C13110542
23	11007_ben (2011-09-29)	gt3x	29-Sep-2011 12:57:00	03-Oct-2011 10:00:00	03-Oct-2011 11:44:35	3:21:02:59	30	NEO1C13110539
24	11007_hofte (2011-09-29)	gt3x	29-Sep-2011 12:57:00	03-Oct-2011 10:00:00	03-Oct-2011 11:44:38	3:21:02:59	30	NEO1C13110541

By pressing the small buttons above the column entries, the table is sorted by the entries in that column. The column 'D:HH:MM:SS' (Days, Hours, Minutes, Seconds) is the length of the recording determined by difference between 'Start' and the first-occurring of 'Stop' or 'Down' (the number of seconds are not exact due to small timer deviations of the AG units). 'Start' must be identical for the AG set belonging to the same subject. Sample rate must be 30 Hz for the AG units.

The column 'Type' refers to file extension of the data files. The Acti4 programme recognises two data file types: 'gt3x', the raw data downloaded with ActiLife version 5 and 'act4' the internal Act4 file type, which can be either converted Actigraph or Axivity data.

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Single file viewing

This menu item, which is used for preliminary viewing and quality control of data analysis, opens this window:
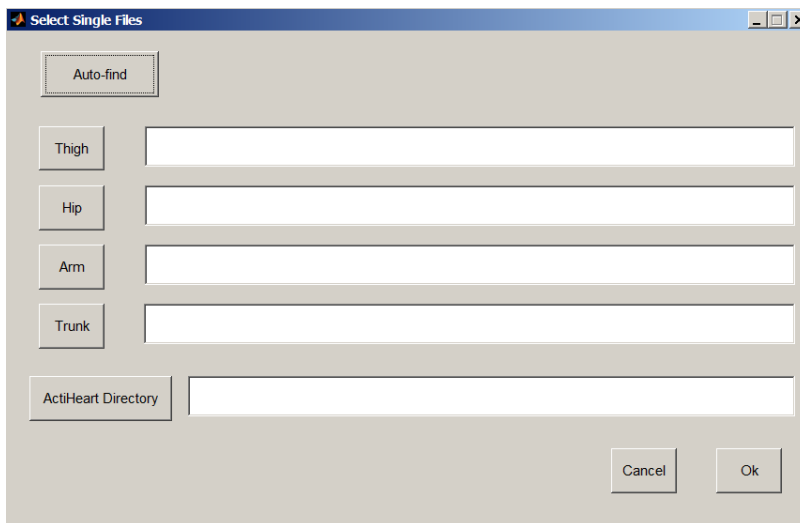

By pressing the button 'Auto-find' a file selection window is opened, for example:
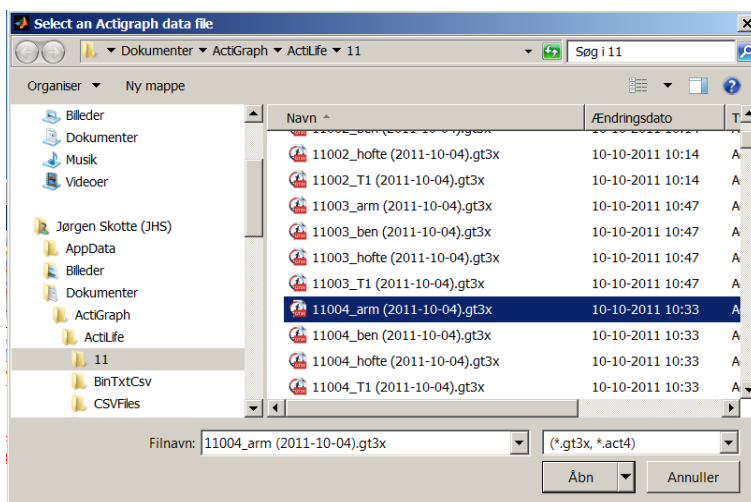
Here you need to select one of the files in the set of AG files for the subject you want to analyse and the other files in the set will automatically be selected provided that the files comply with the naming convention above. If the files don't comply with the naming convention they can be selected individually by the buttons 'Thigh', Hip', 'Arm' and 'Trunk'. Finally, an 'ActiHeart Directory' should be selected if a corresponding AH measurement exists for the subject.
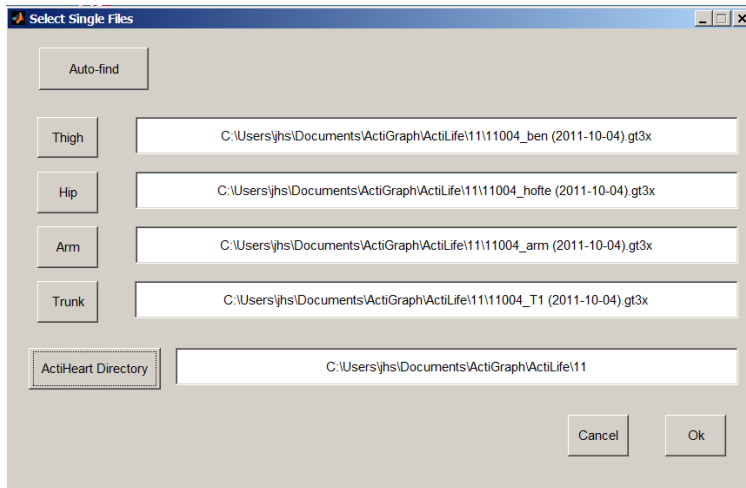
By pressing the 'Ok' button a window like the following appears:
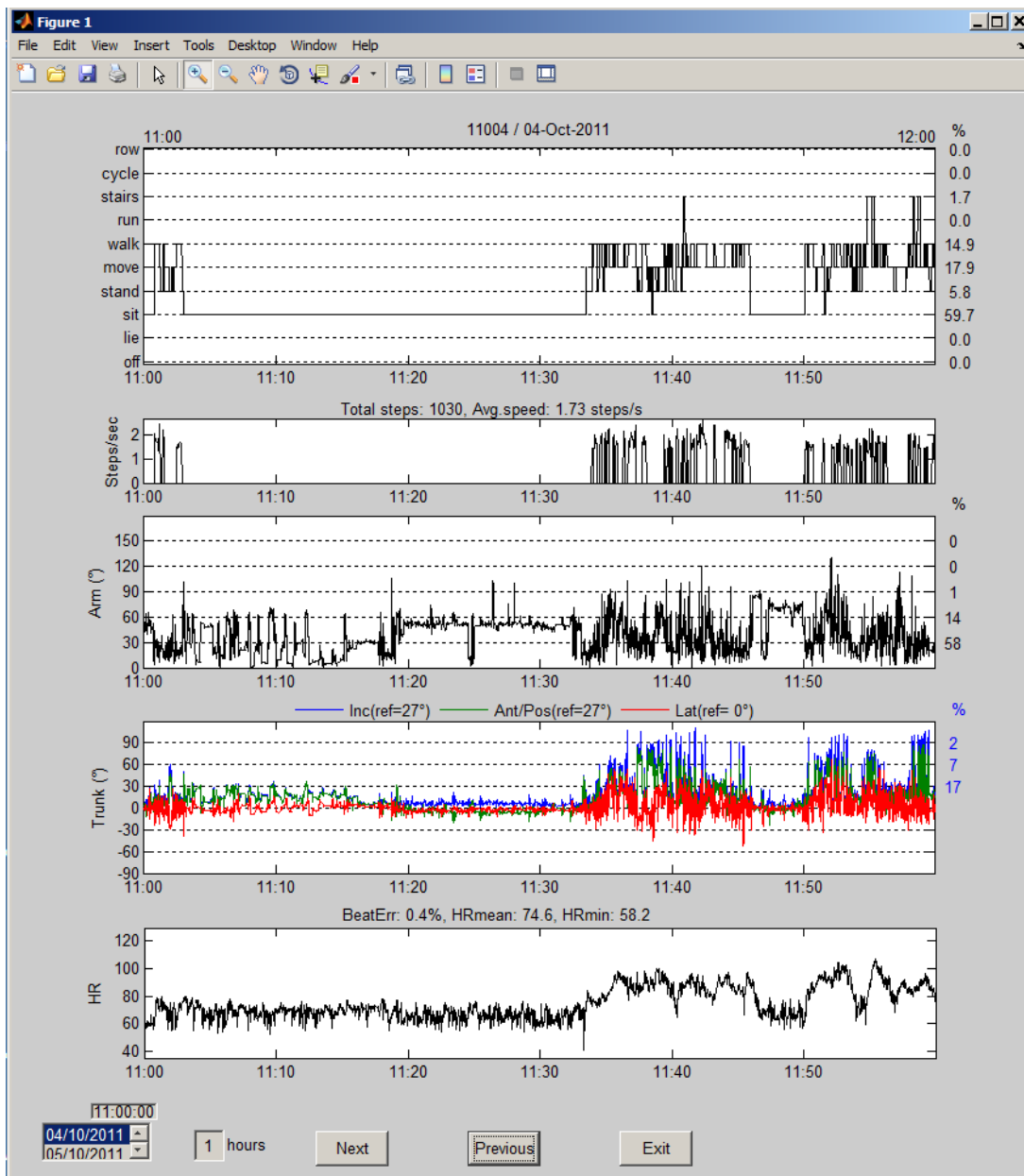
This is the screen output showing the main analysis for one hour of recordings by 4 AG and 1 AH unit. Other values of start date, time and length of period can be selected in the lower left side of the window. The buttons 'Next' and 'Previous' select adjacent intervals for scrolling (equal sized intervals).

The top graph is the activity time series showing the activity categories at the left y-axis and percent of time spent in each category at the right y-axis. The graph below shows the speed when walking (including walking stairs) and running; furthermore the total number of steps and average speed (steps/second) are calculated for the interval shown.

The middle graph shows the arm inclination; the right y-axis shows the percentage of time with arm inclination above 30°, 60°, 90°, 120° and 150°, respectively.

Below is shown the posture of the trunk, blue curve: inclination ([0°,180°]), green curve: anterior/posterior angle ([-90°,+90°], positive for anterior) and red curve: lateral angle ([-90°,+90°], positive for left). The right y-axis shows the percentage of time with trunk inclination above 30°, 60° and 90°, respectively. For this graph it is assumed that the AG unit is positioned at the trunk with its x-axis tilted 27° (mean of a large data set) relative to the trunk axis. This means that the trunk angles in this graph should be considered approximative only, because the actual tilt angle of the AG unit at the subjects trunk is unknowned. However, in the menu item 'Batch analysis' calculations are done in which the actual tilt angle is included (se menu item 'Batch analysis')

The lower graph shows the heart rate (HR). In the heading of this graph are shown the percentage of error classified beats, mean and minimum HR for the interval.

Interval setup

This menu item, which is used for entering subject diary data on work, leisure and sleep hours into a Setup file, opens the below, left window. Press the buttons 'Select AG directory' to select an AG directory containing the AG data files and 'Select AH directory' to select an AH directory containing AH data files. Acti4 accepts AG gt3x data files created with ActiLife version 5 and internal act4 data files. If ActiLife version 6 is used for downloading of AG data, these data must be converted to csv files by ActiLife, and then converted to act4 data files using the menu item 'Convert ActiGraph CSV-files' (se below). Then press the 'Create' button for creating a Setup file and window might look as shown below to the right:
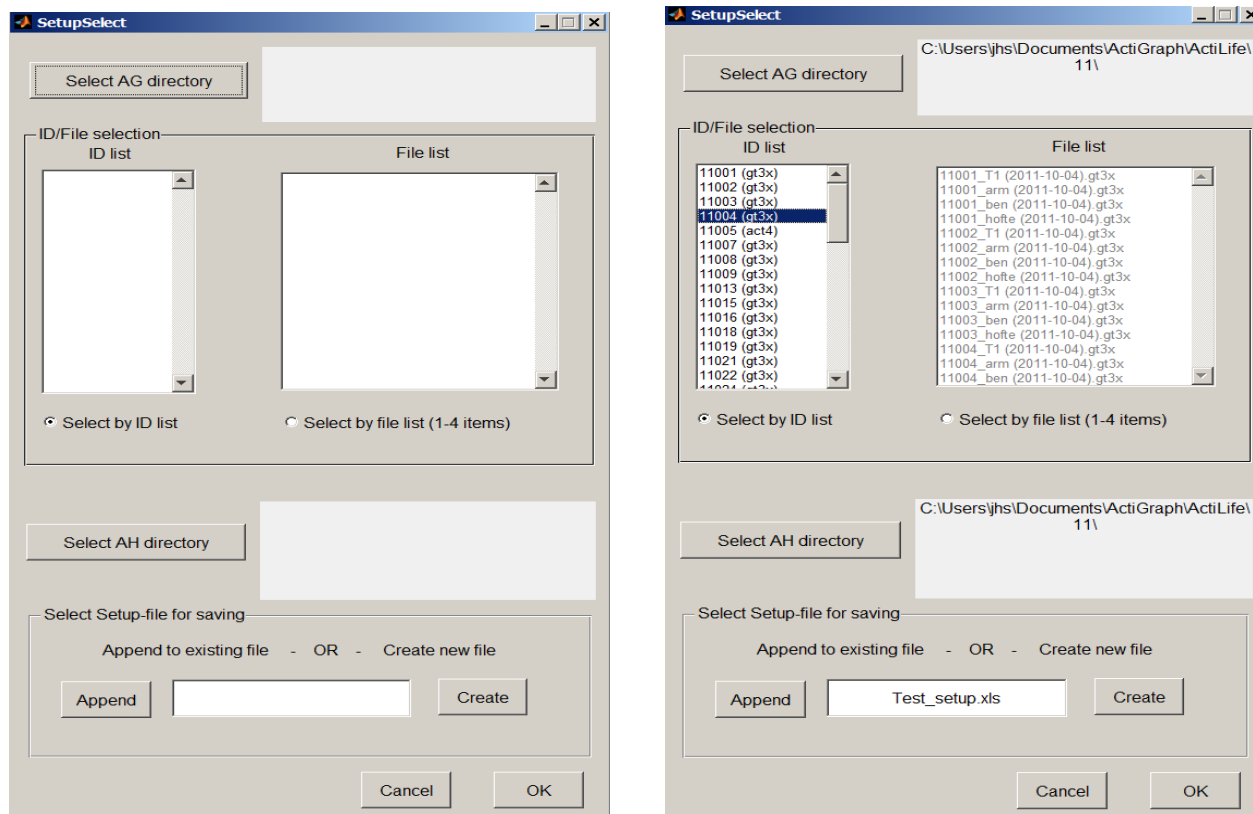
Select the subjects by the' ID list' if the files comply with the standard naming convention (se menu 'File information'). If the files do not comply with the standard naming convention, files for one subject can be selected by the 'File list'.

Now press 'Ok' to continue and the 'IntervalSetup' window appears:
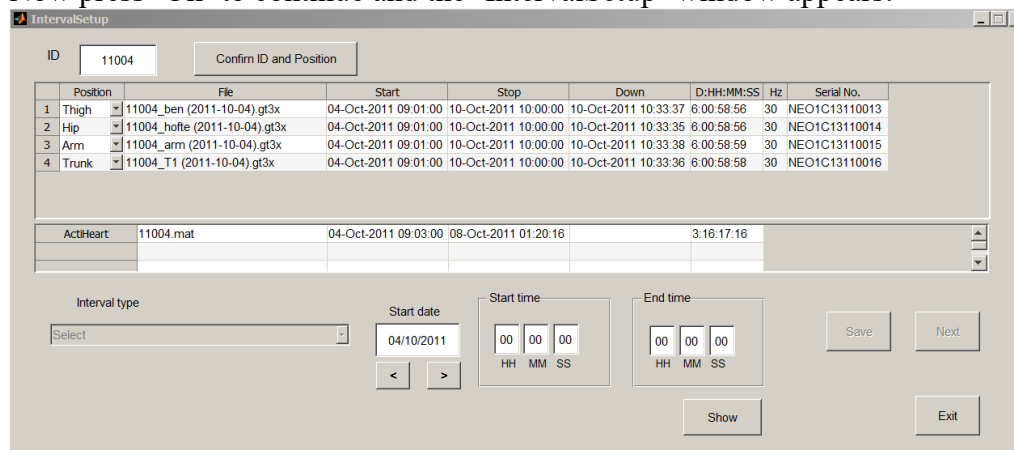
Check that the AG files and position correspond (if not consider to rename the files or use the drop-down menus in the column 'Position' to reassign the files to the correct positions) and press 'Confirm

ID and Position'. This will make the 'Interval type' menu to be selectable and 'Select' opens the drop-down menu below (The text for the Interval types A1, A2,…D is user selectable, see the menu item 'Analysis setup') . Now use the diary data to select the interval type, start date, start and end time of the period. The length (end – start) of any interval must be less than 24 hours. Make sure that all intervals entered are included in the start/stop intervals for all accelerometers; because of some synchronization inaccuracies, it is recommended to leave a minor clearance to the start/stop times, e.g. ½ minute

If one (or more) of the AG unit have not been worn in a period, it can be specified by selecting the point 'E. Actigraph(s) worn/not worn', which will open this menu:

Periods with 'Not worn' AG units must not overlap e.g. if the AG arm is not worn in the period 14:00-18:00 and the trunk AG is not worn in the period 16:00-18:00, two setup intervals specifying the not worn pattern must be selected, 1) 14:00-16:00 AG arm not worn and 2) 16:00-18:00 AG arm and AG trunk not worn.
The 'Show' button in the IntervalSetup window opens a window similar to the analysis window for the menu item 'Single file viewing'.

The Setup file includes a sheet 'Info', which look like this:

It holds information on the name of the directory of the AG data files (named GT3Xdirectory or AGdirectory) and AH data files and furthermore a list of subject running numbers (ID) (If AH data exists the running number is also found in the 'AH' column). The clolums Age, HRrest (resting heart rate) and HRmax (maximum haeart rate) are optional and must be completed manually. If data exist for HRrest and either Age or HRmax, the final calculation will include several parameters of heart rate reserve (HRR). If data exist for HRmax, it will be used for the HRR calculations. If HRmax is empty, HRmax will be calculated from the Age by the formula HRmax = 208-0.7*Age.

The Setup file contains a sheet for every subjects (ID) with the filled in diary data lik this:

Batch analysis

The 'Batch analysis' menu item opens a window for selecting a Setup file ('Select file') and selecting one or more subjects (ID) for analysis.
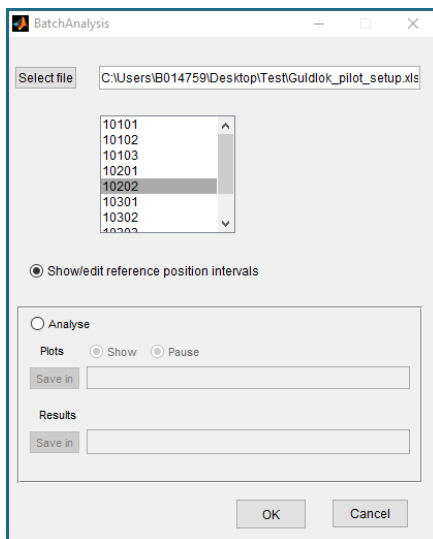
The analysis should normally include 3 steps:
1) check and edit the reference position intervals (optional)
2) check and edit the work/leisure/sleep intervals
3) run a batch analysis

Check and edit the reference position intervals

Note that recording of a reference measurement are optional. If no reference recording is found Acti4 will estimate reference angles for each measurement interval from periods of walking.

If reference recordings have been made: Select the subject (ID) and press the 'Ok' button and the following window appear, which is the first of the reference intervals:
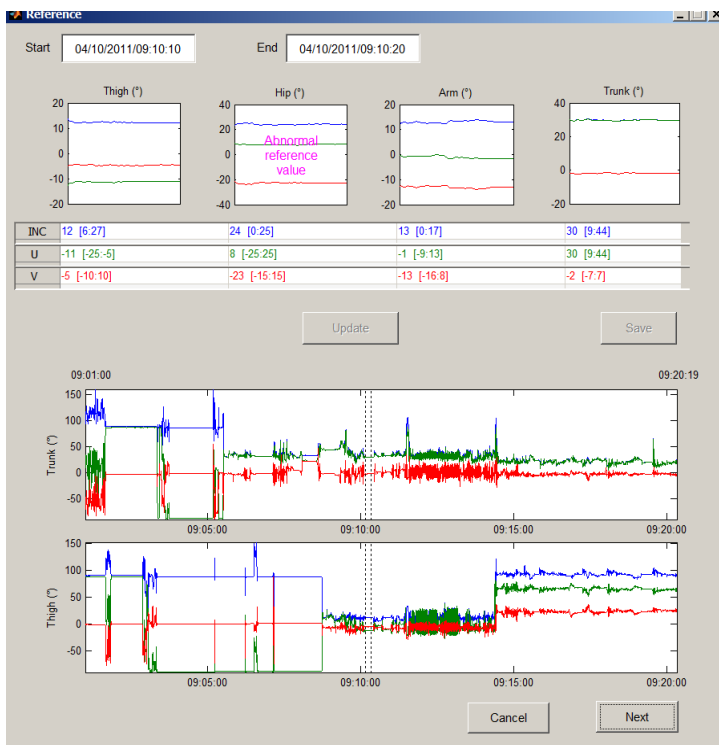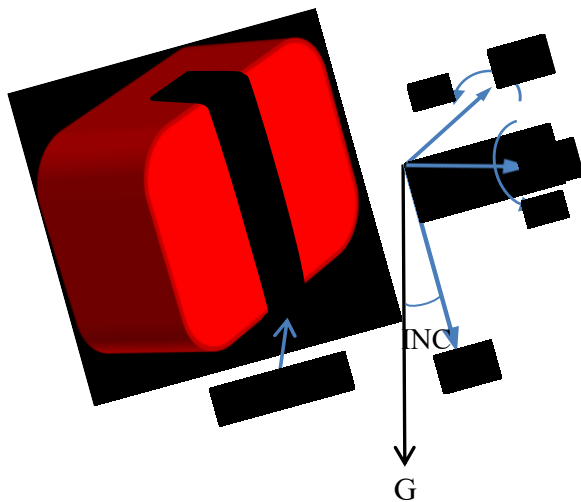
Orientation of the Actigraph accelerometer

The 3 accelerometers of the Actigraph are orientated according to the axes X, Y and Z (X- and Y-axis are parallel to the front surface of the Actigraph and Z-axis is perpendicular to the surface).
INC: Inclination, angle between the X-axis and the gravitational direction G [0,180°].
U: Forward/backward rotation about the Y-axis [-90°,+90°].
V: Sideways rotation about the Z-axis [-90°,+90°].

The bottom graph shows the trunk AG orientation for a 20 minutes period in which the reference interval are marked with the vertitical dashed lines in the center of the graph. The upper 4 graphs show the orientation of the all 4 AGs for the reference interval. By zooming (right click and draw a rectangle) in the lower graph and pressing the button ' Update', the zoomed interval is transferred to the upper 4 graphs. The button 'Save' will save (overwrite) the updated (zoomed interval) to the Setup file. The button 'Next' will read and plot the next reference interval from the Setup file.
In all graphs 3 curves are shown: the blue line (INC) represents the inclination of the AG's x-axis (0-180°). The green line (U) is forward/backward angle of the AG ([-90°,+90°], positive for forward) and red curve (V) is the sideways angle ([-90°,+90°]). The table below the 4 upper graphs lists the average values of the angles INC, U and V for the selected time period and furthermore a compliance interval representing ±2 standard deviation for these angles based on approx. 250 recordings (subjects). It is indicated in graph area, if the actual value is outside this interval (Abnormal reference value).
When stepping through the reference intervals, the accepted reference values are summarized in the window 'RefValues', for example

This sequence of reference values (recorded during a 6 days period) is considered quite stable and indicates that position/orientation of the AGs remain fixed during the measurement period and that the subject takes the same posture during the reference recording. Reference positions, which cannot be

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recognized or considered as outliers, should be 'removed'. This is done by manual editing of the current line in the Setup file from 'F. Reference' to 'Reference'; then Acti4 will not read the line (remember to save the Setup file).

Check and edit the work/leisure/sleep intervals
This is the second step in the batch analysis. Note that during batch analysis an error checking option can be selected (Analysis setup, Check during batch run), which checks for correct accelerometer orientation.
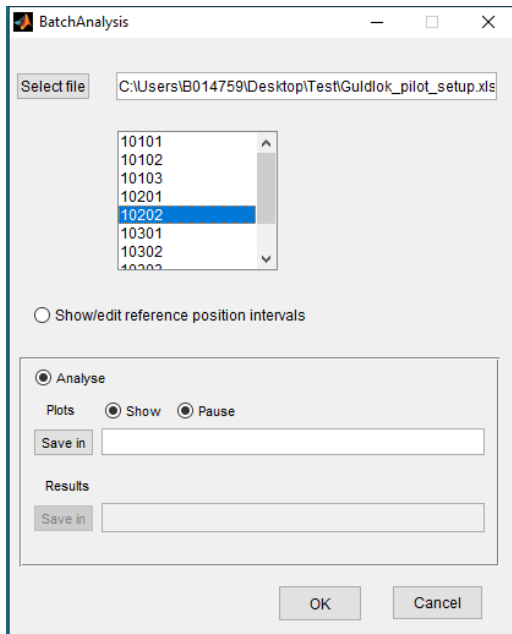
Check the radio button 'Analyse'. 'Show' and 'Pause' is checked by default in order to send graphics output to the screen and pause between the presentations of intervals to analyse. Select the Setup file and press 'Ok'. This will bring up the two windows below showing the analysis of the first interval of for selected subject in the Setup file:
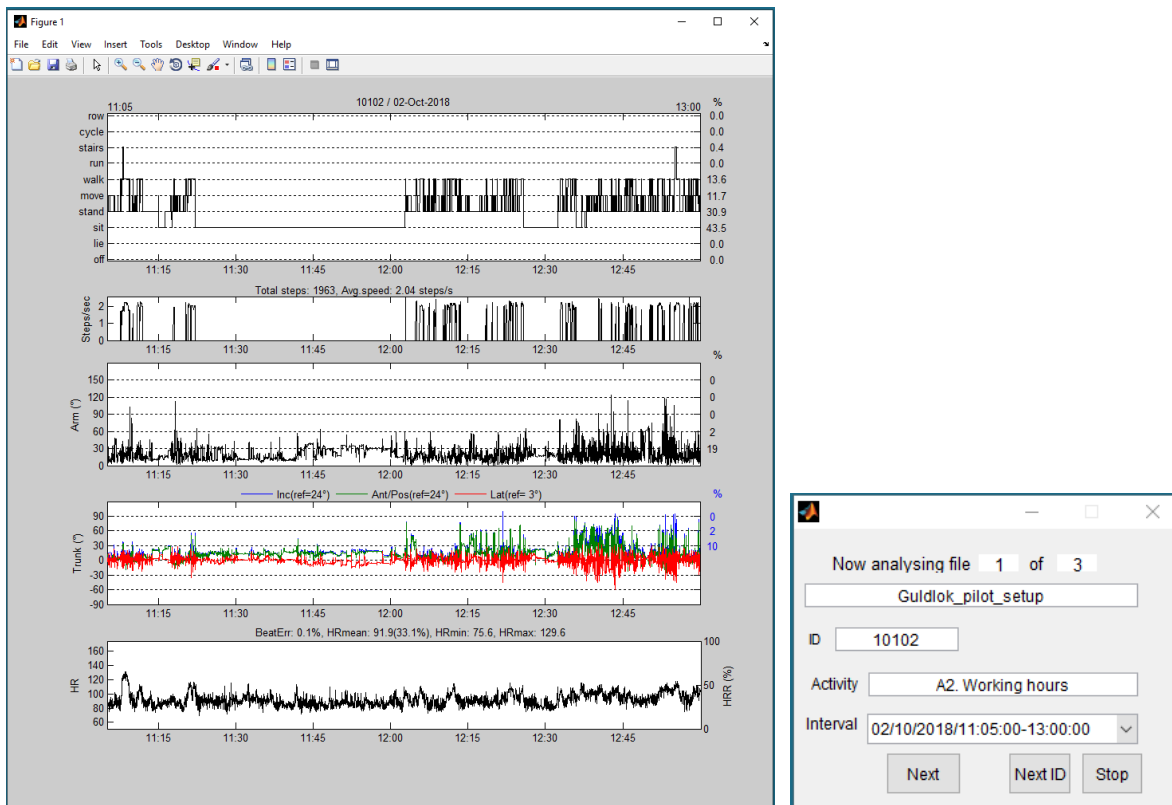
The left window is similar to the analysis output in the menu item 'Single file viewing'; however the selection of intervals to analyse is made by the right window 'Now analysing'. During the batch analysis, reference angles are included in the data analysis (median value of the accepted reference values, if manual reference positions have been included). For the trunk AG this value is stated in the heading of the Trunk graph.

If an AH recording is included in the measurement, the synchronization between the AG recording and the AH recordings must be checked because this is often erroneous: First make sure that AG and AH recording seem to be roughly coherent during or after work time. Look for pronounced changed in activity (e.g. sitting to walking etc.). This will normally show if the recordings is roughly (within a couple some minutes) coherent. Then go to a sleep recording and zoom into an interval including a few, marked trunk movement and zoom further into a single movement and make sure that the movement and increase in HR are simultaneous (within a couple of seconds). If the AG and AH recordings are not concurrent, a correction should be made by selecting the data cursor tool ⌖, and marking a point in trunk (or arm/activity) curve and a corresponding point at the HR curve. This procedure wil save the time difference between the marked point in the Setup file. If the time difference is large i.e. a few minute or more, it is recommended repeat the procedure to fine tune the time offset setting (select Batch analysis again so the previous offset setting is recognized). The timestamp for the point marked with the cursor tool is also copied to the windows clipboard.

Generally, it should be considered if the analysis seems reasonable. It is important to know the character of the work (e.g. is it expected that sitting or walking are prevailing). It is often possible to consider if time for bed and rise are plausible (especially the rise time). Evident errors should be corrected (edit directly in the Setup file and save); 5 minutes are considered a triviality limit. Examples of abnormal recording that should be further examined are: almost no walking is found when plenty of working is expected, no sitting is found during a work day, walking stairs (or cycling) all the time (a lot of short periods). These cases indicate that the some of the AG units could be exchanged by mistake or wrongly orientated. Special attention should be paid to periods following episodes in which the AG unit(s) has not been worn. 'Not-worn' intervals in are showed by a yellow curve. These intervals are either included in the Setup file (according to diary data and/or investigator

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assessment) or estimated by Acti4, which consider daytime periods without movement for 1½ hour or more to be not-worn periods (in special cases Acti4 might estimate shorter periods as not-worn)

Run a batch analysis
This is the last step in Bach analysis. Uncheck the radio button 'Pause', press the button 'Save in' and enter a filename for saving the analysis to a comma separated text file, which easily can be imported by Excel (the software suggest a name consisting of the Setup-file name plus '_RES'). Plot can be shown during the batch run and saved as pdf-files if the radio button 'Show' is checked and a file names is entered.
In order to calculate relative heart rate capacity (HRR) data, the age of subjects and resting heart rate must be entered into the 'Info' sheet of the Setup file. By making a preliminary Batch analysis the resting heart rate can be calculated and entered into the 'Info' sheet.

Besides the above results file a text file is saved (fixed name: above results file name with the addition of '_REF' at the end) giving a number of basis information for the actual run (setup file name, data directories, analysis setting etc.) and reference angles calculated from the reference intervals for all subjects.

Inclinometer data viewing

This menu item opens a window with 4 graphs plotting the acceleration data of the AGs interpreted as angles. The 3 curves represent inclination of the x-axis (Inc, [0°,180°]), forward/backward tilt (U, [-90°,+90°]) and sideways tilt (V, [-90°,+90°]) of the AG unit. Start date and time and length of interval are entered in the bottom part of the window.
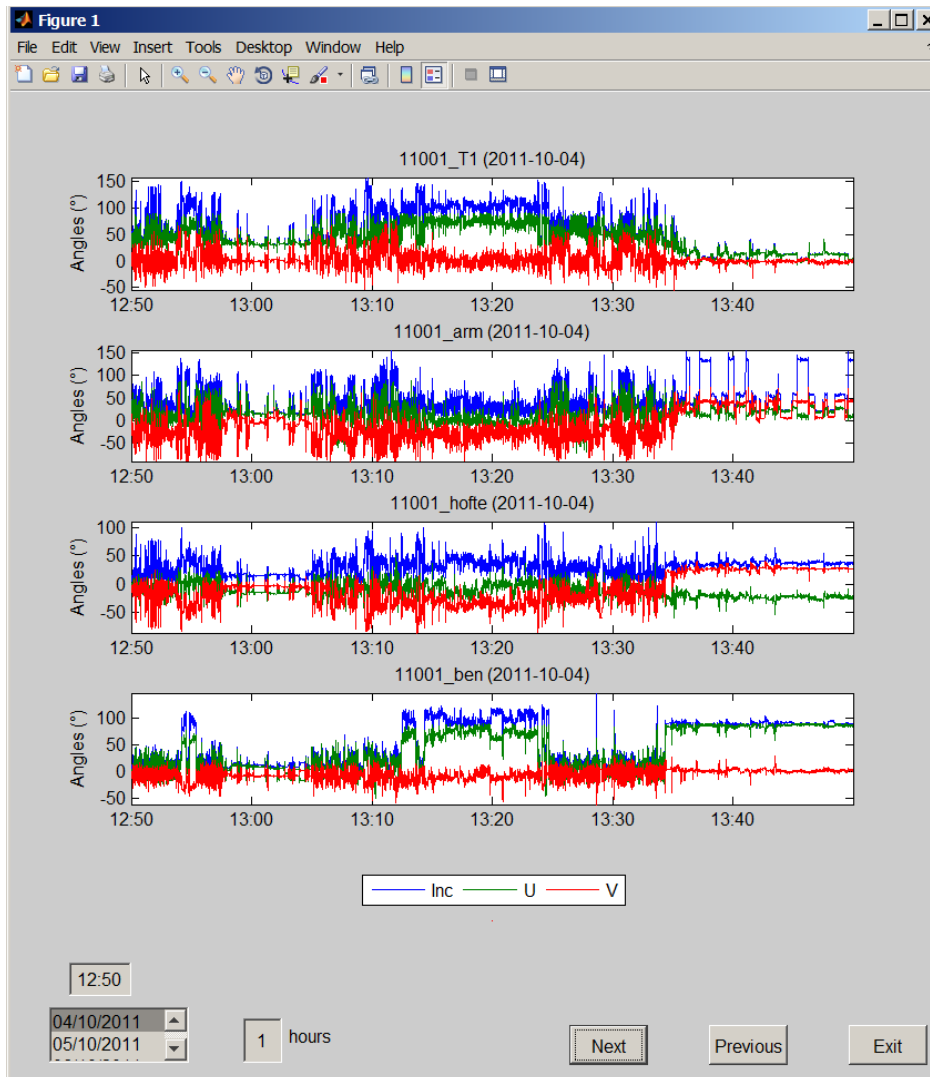
Raw data viewing

This menu item opens a window holding graphs showing the acceleration in units G recorded for the 4 AG units in all 3 directions. Start date and time and length of interval are entered in the bottom part of the window. Note that y-axis of the graphs are auto-scaled (different y-axis in the graphs).
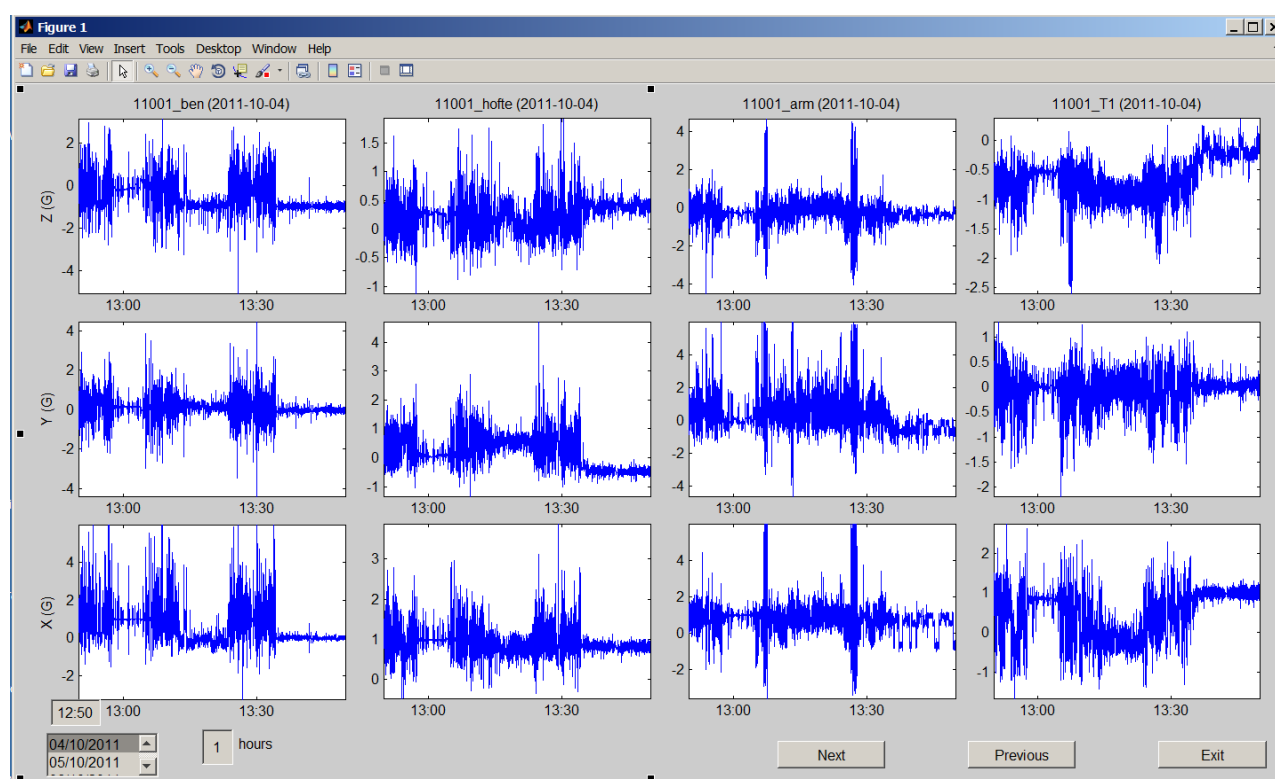
Convert ActiGraph CSVfiles

This menu item is used for converting ActiGraph csv files to the internal file format 'act4' useed by Acti4.

In ActiLife version 6 the gt3x files are compressed and Acti4 cannot directly read these files, so data downloaded with ActiLife version 6 must be converted to the 'act4' type specially designed for use by Acti4. This conversion includes two steps, first the raw data files (gt3x) are converted to text files (csv) by ActiLife (File>Import/Export>GT3X->CSV). Then the created csv files are converted to 'act4' files using the above menu item.

The gt3x files downloaded using ActiLife version 5 are directly readable by Act4 and do not need conversion to 'act4' format.

Calibration of accelerometer recordings and change of accelerometer axes can be performed in this stage of conversion csv-files to act4-files (see menu item 'Convert AX3 CWA-files').

Convert AX3 CWA-files

This menu item is used for cnverting Axivity raw files (cwa files) to the internal act-format used by Acri4.

The first window shown is used for specifying if accelerometer calibration should be carried out (default) and for potential change of acceleromer axes in case of a non standard accelerometer orientation.

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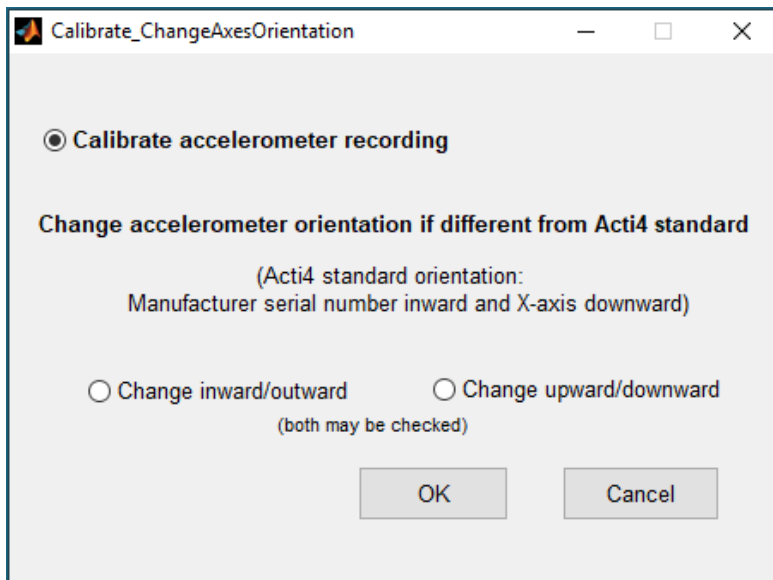
If calibration is not carried out during this conversion stage, act4-files can be calibrated afterwards (see menu item 'Calibrate act4-file')

After presssing OK a standard file selection window is shown for selection of the raw AX3 data files (cwa files) for conversion. The selected files then appear in a table for specifying the accelerometer positions (check one column for each file):

The files in the above example (subject ID 99001, AX3 serial numbers 18816 and 31095) will be converted to files with names: 99001_Thigh_(2015-04-14)_18816.act4 and 99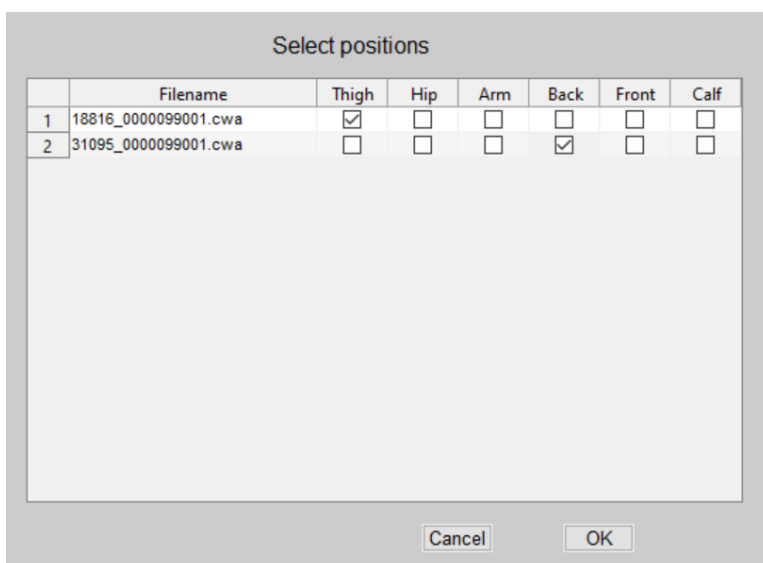001_Back_(2015-04-14)_31095.act4, repectively (2015-04-14 is the date for start of the recording). The results of the calibration procedure are shown in an Excel sheet (see menu item 'Calibrate act4-file').

Convert Sens bin-files

This procedure is similar to converting Axixity CWA-files. The files to convert must be binary files exported by the Sens software (Export/Accelerometer/Raw/Binary). Before conversion the files must be renamed so the first 5 characters of the filename specify the ID number and the characters 7 to 14 are the Sens serial number.

Convert ActivPAL CSV-files

This brings up a standard file selection window for selection of compressed or uncompressed csv exported ActivPAL (aP4 mode) data files for conversion to the internal act4 format used by Acti4. Calibration of accelerometer recordings and change of accelerometer axes can be performed in this stage of conversion csv-files to act4-files (see menu item 'Convert AX3 CWA-files').

Convert ActiHeart IBI-files

Downloaded ActiHeart data are store in an Access data base. These data must be exported to Inter-Beat-Interval (IBI) text data (In the Actiheart software, make a Bulk Export selecting Time-stamped IBIs). This involves the creation of a text file for every subjects (the filename must be identical to the subject's running number used for identifying AG recordings (5 digits)). These IBI text files must be converted (to matlab 'mat' files) using the above menu item. This conversion is time consuming and may last 1-2 minutes for a one week recording.

Convert Firstbeat files

Acti4 supports heart rate recordings made by the Bodyguard 2 (Firstbeat) logger. Raw data, sdf-files, obtained by the Firstbeat Uploader must be converted to 'mat' files analogous to Actiheart files. When downloading data with the Firstbeat Uploader, 'firstname_lastname' must specify the subject's running number (5 digits) and the Bodyguard number like 'ddddd_Xxxx' where ddddd is the subject running number and Xxxx specifies the Bodyguard unit. If the Bodyguard's accelerometer is enabled, these data can be used in the same way as data recorded by a separate trunk accelerometer. However, first the csv.zip files containing the acceleroneter data must be manually unzippped (standard windows procedure).Then when selecting the sdf (HR data) files, select also the corresponding csv (accelerometer) files. The accelerometer data will then be converted to an act4 ('front') file similar to data from a separate accelerometer at the subject's front. Breaks in the HR recordings result in 'not worn' periods for the accelerometer data when analysed by Acti4.

Calibrate act4-files

A procedure is included for calibrating accelerometer recordings automatically. Select the act4-files to be calibrated, and select a folder for saving the calibrated files, which will have the same names as the uncalibrated recordings. If no save folder is selected, the calibration procedure is run without saving anything. The calibration procedure requires that a sufficient amount of 10 seconds epochs for different orientations without movement is found in the recording (a 24 hour recording will normally meet this requirement). Information on the calibration for each file is displayed in an Excel sheet: The outcome of the calibration procedure can be 'OK', 'Uncertain' or 'Failed'. Details are also provided about number point in the calibration data set (Npoint), minimum volume of convex hull for the dataset (HullVol), calibration error (Err, mean absolute value of residuals by fitting data set to an ellipsoid), calibration coefficient in each direction (Ax, Bx, By, By, Cz, Cz) and an estimated p value for the risk of any of the calibration coefficient to be more than 0.05 off. For p-values less than 0.05, the calibration result is 'OK', and 'Uncertain' for p above 0.05.
Calibration can also be carried out during the conversion of raw accelerometer (Axivity/Acti-Graph/ActivPAL) data to act4-files.

Synchronize act4-files

A procedure is included for synchronizing accelerometer measurements for recordings where more than one accelerometer have been used. By selecting a set (or more sets) of act4-files belonging to the same recording i.e. a thigh measurement and one or more accelerometer measurement for other positions, all measurement will be synchronized with the thigh measurement as a reference. For every 30 sec. a covariance analysis is made between the acceleration at the thigh and the other positions, then a robust linear fit is carried out for intervals with significant correlation. This determines the lag between the thigh acceleration and the other accelerations, which is used for synchronizing/resampling the acceleration data for the other positions. The synchronized set of accelerometer

measurements is saved with the same file names in a selected folder (if no folder is selected, the synchronization procedure will be run without any saving). An example of the synchronization procedure is shown below. If the median average deviation (MAD) for the robust fit exceeds 1 sec. or the intervals used for the robust fit span less than 25% of the entire range, a warning of uncertain synchronization is shown.
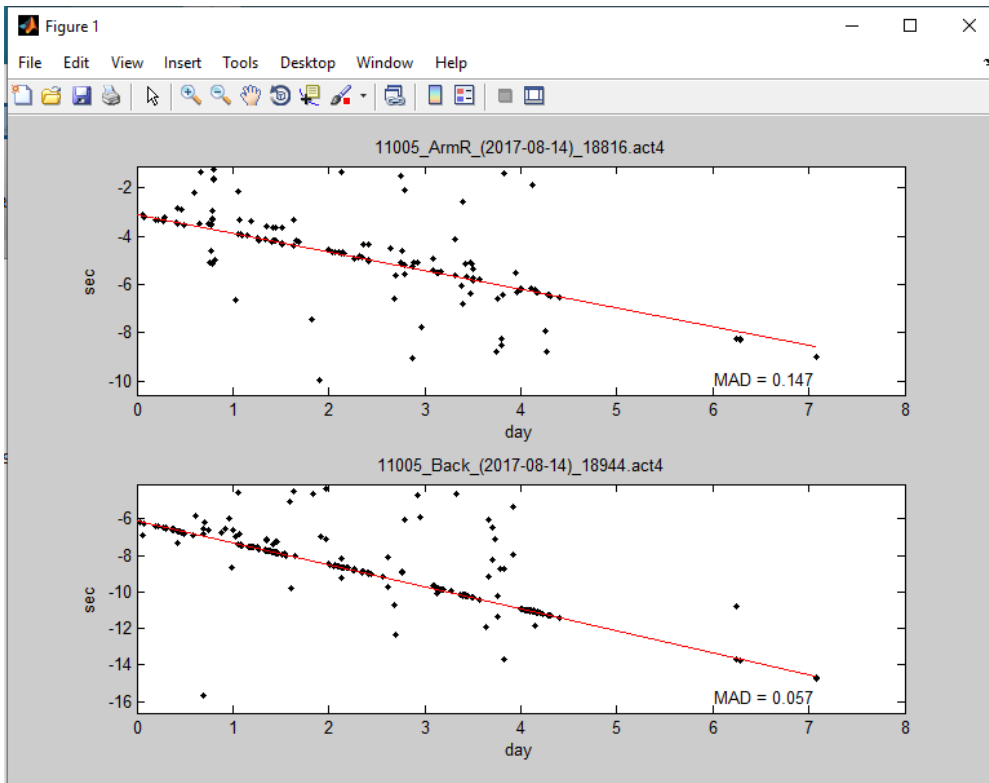

Outlier check

After running a 'Batch analysis' it is recommend to checik the results for outliers. By running this menu item, you are first asked to select an output file from a 'Batch analysis' and its associated Setup file. Then this window apears,
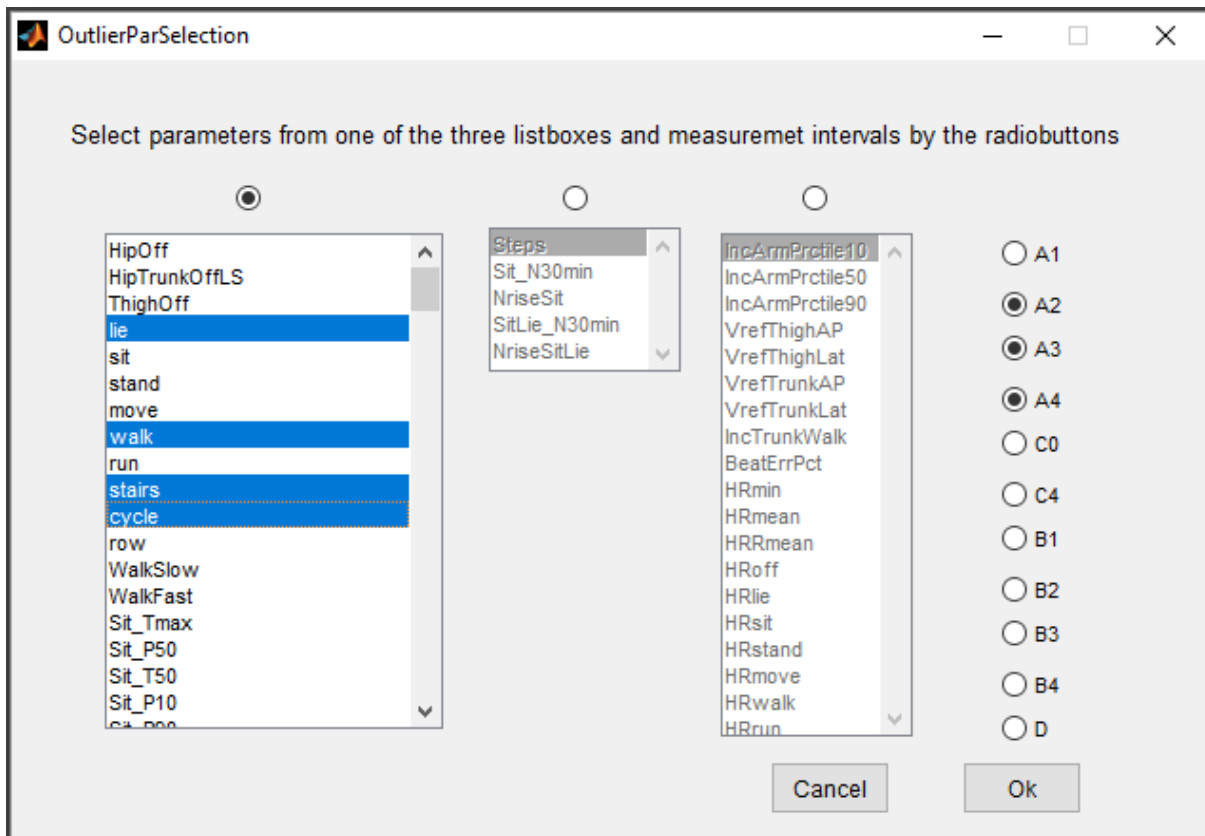
which lists the parameters from the batch output collected in three groups: Group 1 (left one) consists of parameters with the unit of hours, group 2 (middle one) contains of parameters, which is just a number, and group 3 consists of parameters representing different mean values for a measurement interval (degrees, percent or beat per minute). Proceed by selecting one of the groups and a number of parameters from the group and one or more interval types from the right column of radiobuttons.

This will provide a bar plot with one subplot for each selected type of intervals and bars for each selected parameter. In the below example, four parameters from group 1 are selected and the hight of bars show the percentage of measurement which is considered as outliers. Outliers were considered according to two criteria, values (black bars) with a distance of more than 1.5 times the inter-quartile range from the quartile values (Tukeys fence), and values (red bars) with a distance of more than 3 times the inter-quartile range from the quartile values (extreme outliers).
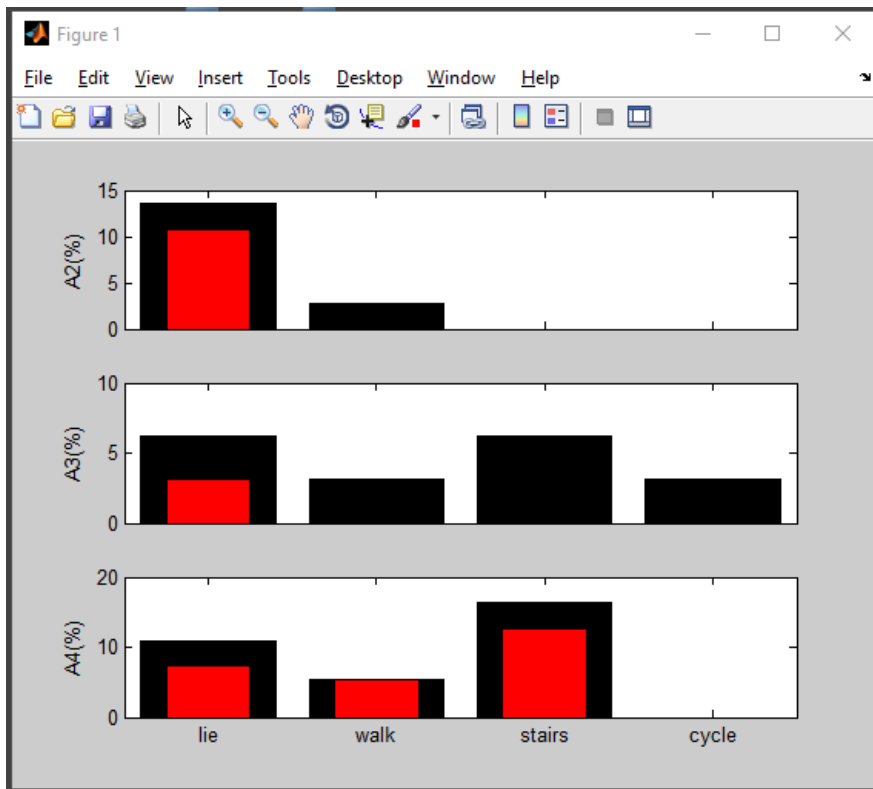
By clicking at one of the bars, details on values from the actual type of interval and parameter show up: The table to the right lists the ID, Start time and parameter values for the intervals were the outliers were found. In this example the parameters were selected from group 1 (time parameters), so both the hours and time as percentage of measuremt duration are listed. In the left plot all measurement values (percentage) are shown for the selected interval type/parameter.Outliers are shown by black circles, extreme outliers by red circles and values in the inter-quartile range by green circles.

If the parameters are selected from group 2, both the actual number and the number scaled to an eight hour period are shown in the table. No scaling are used for parameters in group 3, which represent mean values for a measurement interval.
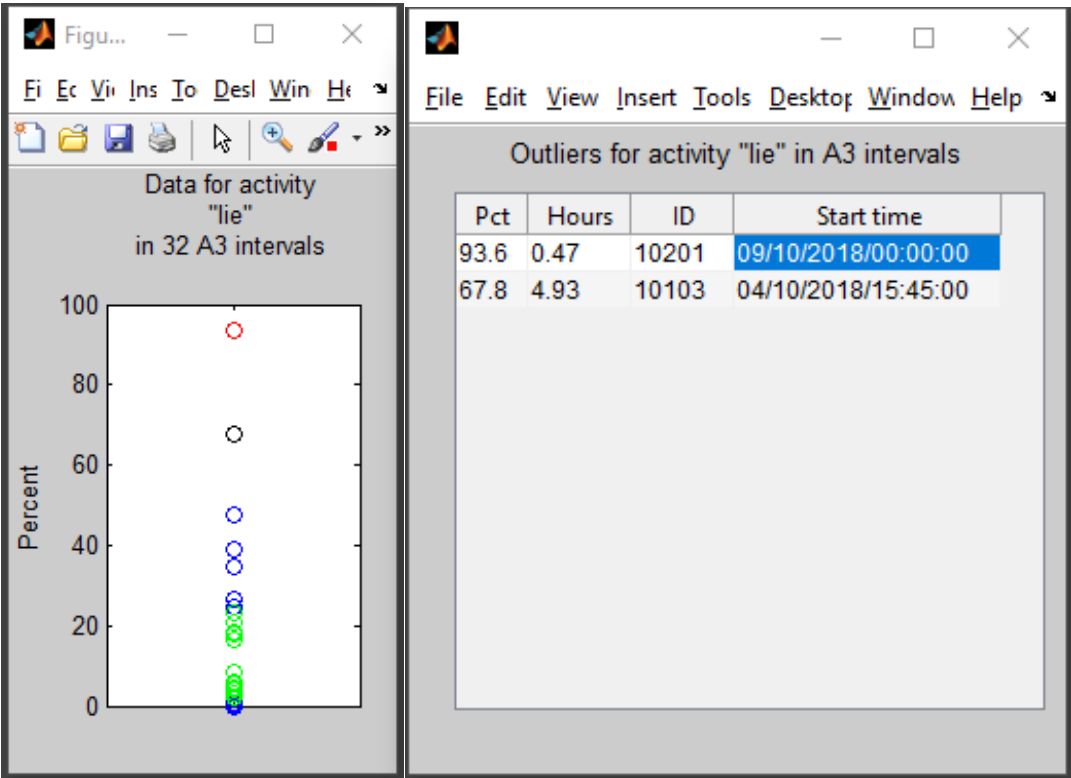
By clicking any of the cells in the outlier table, a figure showing the standard analysis for measurement interval shows up:
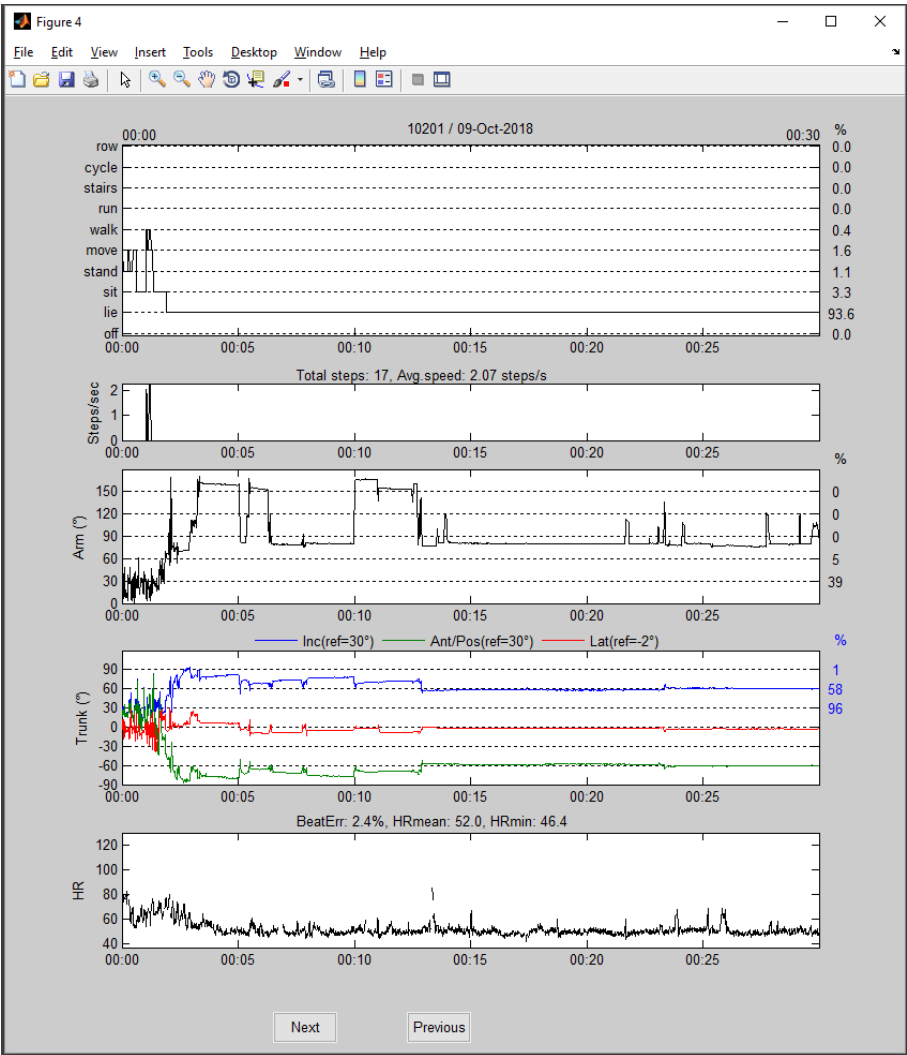
Aggregate results

This menu itemis used for calculation of average 'per day' values for recordings including more than one day.

First select an output file from a final batch run, which has been prepared by checking the analysis option 'separate periods in days', and select the parameters and IDs to include in the aggrgation. Then select either a detailed or a simplified procedure:
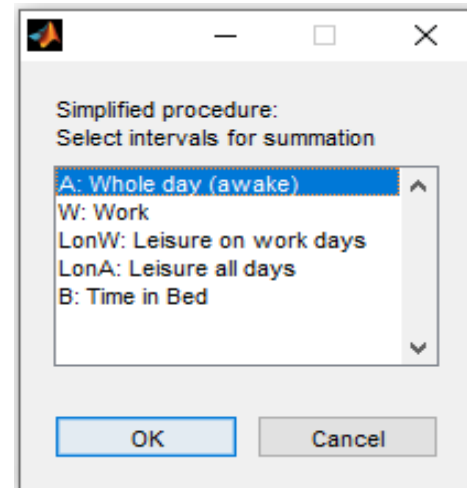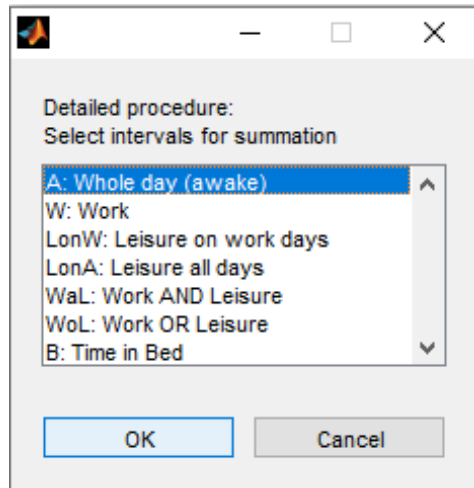
Interval the same day are either summarized (time parameters, hours) or averaged (non-time parameters). Averaging between days in the detailed method is described in the document CriteriaExtractDayResults. For the simplified procedure a time weighted average is used to calculate the mean between the days.

The calculations presupposes that the intervals A2 and B2 are work intervals, A1, A3, B1, B3 and C0 are leisure intervals and A4, B4 and C4 are night intervals.

Rotate axes

For measurements made with non-standard orientation of accelerometer axes, this menu item makes it possible to rearrange the axes for the act4-files corresponding to any 90° rotation of the coordinate system. The axes reordering is specifyed by this scheme:
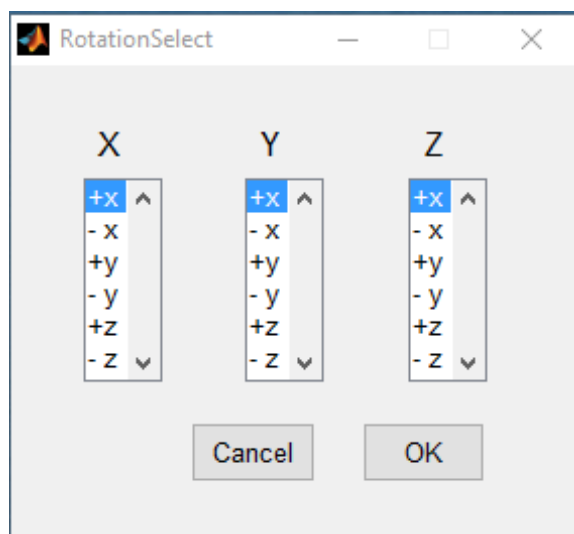
Example: If an accelerometer has been positioned on the side of the right thigh (instead of on the front) with the x-axis pointing downwards, y-axis forward and z-axis outwards, then the axes reordering should be X→ +x, Y→-z and Z→y.

The act-files with the reordered axes are saved in the same folder as the input files, but with a file name specifying the new axes oriention.
The user must ensure that the selected reordering of axes is valid.

Analysis setup

A number of parameters, which determine the analysis made by Acti4, are user selectable.

The list-box 'Select setting' shows the names of the available settings, the Default setting is the only one present at the start. Enter new values in any of the editable fields and press 'Save new setting' for making a new setting that can be used for subsequent caculations. Once new settings are defined/saved, the name will show up in the list-box 'Select setting', and by selection the actual parameter values are shown. Acti4 remembers the selected setting and will start up using the setting from the last run.

By the panel 'Analysis periods' the names can be set up for the actual periods in which the calculations are done. In the results file the periods will be marked according to the letter A1, A2, ,,,D and the selected name. The entries A4, B4 and C4 should only be used for sleeping periods for which the detection of not-worn periods is less restrictive than for the other entries (furthermore, if only the thigh accelerometer is present, it is not possible to differentiate between lying and sitting position, so all lying/sitting during A4, B4 and C4 intervals will be classified as lying, wheras the classification will be sitting for the other interval types).

By the panel 'Activity classification/Minimum bout length' the minimum bout (seconds) can be selected for all type of activities. An activity must generally last this number of seconds to be recognized, otherwise it wil be overruled by longer lasting neighbourring activities.

Panel 'Threshold':

The activity is classified as 'stand' (still) if the maximum of the standard deviations of the accelerations for the thigh accelerometer is below the 'stand/move' threshold and the inclination is

below the 'sit/stand' threshold. The activity is classified as walk if the standard deviation of the longitudinal acceleration of the thigh accelerometer is above the 'stand/move' threshold and below the 'walk/run' threshold (and below an individual 'stair' threshold, which is not user selectable). Average inclination of the thigh above 'stair/cycle' threshold cassify for cycling.

Intervals, which include parts of 2 days, are divided into 2 intervals and separately analysed if the options 'Separate periods in days' is selected. For example an interval starting at 22:00 and ending 07:00 the next morning is divided into the 2 intervals 22:00-00:00 and 00:00-07:00 for the analysis.

By checking 'EVA analysis' Acti4 will calculate a set of activity variation variables for the dataset (saved in a separate file, se document EVA analysis by Acti4.pdf).

By checking 'HRV analysis' Acti4 will calculate a set of HRV (heart rate variability) variables for the dataset (saved in a separate file, se document HRV analysis by Acti4.pdf).

By checking 'Check during batch run' a quality check is performed for each analysis interval during batch run consisting in a test for correct orientation of accelerometer axes, which means that the accelerometers are wrongly flipped up/down, in/out or both. Also, there is a check for confusion of the thigh and trunk accelerometer and a check for trunk angle during walk, which are considered unusual if outside the interval 5-25°. The checking algorithm does only work on daytime intervals including a minimum amount of walk. When the batch run begins, an Excel sheet is opened in which the comments from the checking algorithm are written (Issue to check). The messages should not be taken for complete secure – not all errors will be detected and false messages could occur. If a wrong accelerometer orientation is found throughout a measurement (for nearly all measurement intervals), the accelerometer axes should the corrected by making a new conversion of the raw accelerometer data to act4-file. If accelerometers are mis-orientated just for some intervals, the orientation can be corrected for these intervals by adding the following text in the column 'E' in the setup file for the relevant intervals: ThighXHipXArmXTrunkX where X is 1, 2 or 3. X=1 means an up/down flip, X=2 means an in/out flip and X=3 both flips. For example, if the thigh accelerometer needs to be flipped up/down and the trunk accelerometer needs to be flipped in/out, the text Thigh1Trunk2 should be added in the E-columns for the intervals that need correction.

Export of activity data to csv or matlab files are carried out if the "txt" and/or "mat" options are selected. You will be asked for a folder for saving the exported files during the execution when the first data are ready for saving during program execution (the selected folder will apply for the rest of the Acti4 session; run a new Acti4 session if you want to change the selection). The name of the exported files consists of the subject ID and the start time of the measurement interval (ID_HHMM-mmddyy). The text files consist of 2 comma separated columns with time (dd-mm-yyyy HH:MM:SS) in the first column and activity in the second column (0:off, 1:lie, 2:sit, 3:stand, 4:move, 5:walk, 6:run, 7:stairs, 8:cycle, 9:row). Time increment is 1 second. If the measurements include an arm accelerometer, the output also contains a column of arm inclination (degrees). The matlab files include the variables ID, Time (matlab datenum) and Activity (and optionally Varm). (Files will be overwritten if matching file names are found).

By checking the option 'Include calf accelerometer', Acti4 will detect kneeling position along with the other activities and store the result in a separate textfile. During the Batch run a separate window will show the activity classification for the intervals along with the thigh and calf angles. The calf act4-files must be found in the same folder as the act4-files for the other accelerometers. Kneeling position is detected when the backward inclination of the calf accelerometer is more than 75° (default value, possible to change: Thresholds).

The settings are stored as sheets in the file ParameterList.xlsx. Removing/renaming a saved setting must be done by normal Excel handling of the actual sheets in ParameterList.xlsx (use standard

search methods to find the location of ParameterList.xlsx; do not make any changes to the sheet named 'List').