USER MANUAL

The RepMove Toolbox for Repetitive Movement Analysis

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RepMove toolbox was developed under Matlab version 7.6.0.324 (R2008a). It requires the Matlab toolboxes a) Filter Design, b) Signal Processing, and c) Statistics for its functions. It was also tested with the most recent Matlab version 2019 for its functionality. There is no apriori programming knowledge required for operating the toolbox, hence can be easily used by clinical personnel.

Licensed under the GNU General Public License (GNU-GPL), the toolkit is freely available and can be downloaded from the Github link:
https://github.com/MehmetEylemKirlangic/RepetitiveMovementAnalysis

Three sets of sample data are accessible under:
https://github.com/MehmetEylemKirlangic/DATA

Below, the toolbox functionality is presented under Matlab Version 7.6.0.324 (R2008a):

The folder containing the program files should be chosen in Matlab, or its path should be added to the path list. The toolbox, then can be started like any other Matlab toolbox from the *start* button of Matlab.

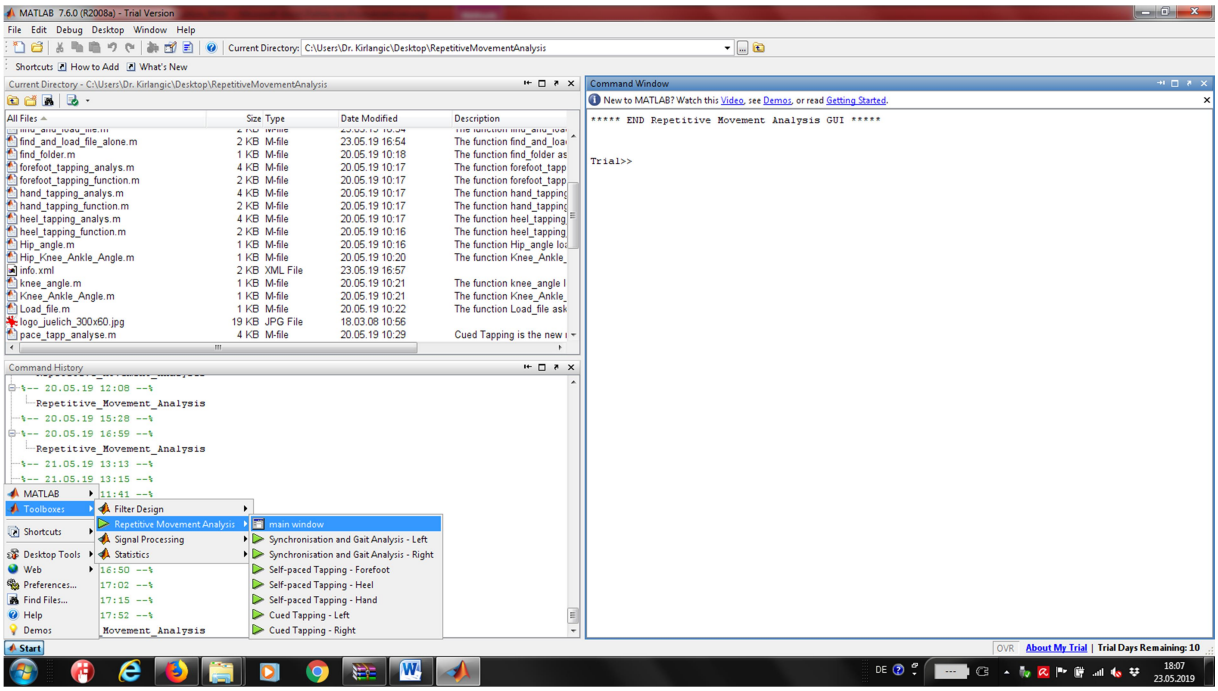

Fig. 1. Starting the toolbox by the *start* button of Matlab.

1. The Main Window Repetitive Movement Analysis

The toolbox consists of a main window with a dropdown menu from which seven further window/analysis options can be chosen. Two buttons, *start* and *exit*, starts the chosen analysis option or quits the toolbox. Pressing the *start* button, the chosen analysis window opens. The dropdown menu options are as follows:

1) Synchronisation and Gait Analysis - Left,
2) Synchronisation and Gait Analysis - Right,
3) Self-paced Tapping - Forefoot,
4) Self-paced Tapping - Heel,
5) Self-paced Tapping - Hand,
6) Cued Tapping - Left, and
7) Cued Tapping - Right.

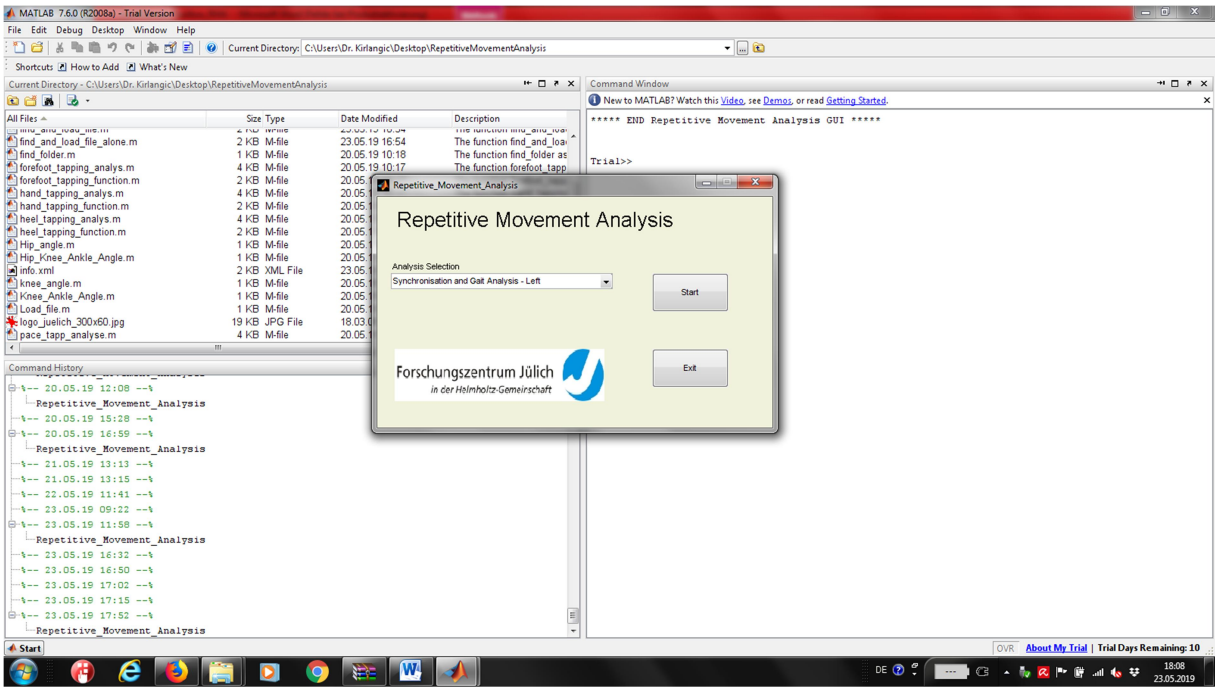

Fig. 2. The main window of the RepMove toolbox.

2. The Windows for Analysis Options

There are three different window templates corresponding to three modules of the toolbox: 1) Synchronisation and gait analysis – Left/Right; 2) Self-paced tapping analysis (Forefoot/Heel/Hand); and 3) Cued tapping analysis – Left/Right. All seven options share following user buttons:

Load Patient Data Button

The *load patient data* button loads the patient data automatically. The ASCII-files of the patients are expected to have standardized names. After pressing the button, the user is requested to select the patient's folder, where the ASCII-files are saved. The program loads then the files, which belong to the active window. Once the files are loaded, the graphs are

displayed. The ID of the patient is taken automatically from the folder's name and displayed in the field *Patient ID*.

If a necessary file does not exist or if there is an error in the ASCII-file's name, the active window returns a message that this file does not exist. In this case the *load file* button(s), which is/are positioned at the upper right corner of each graph, is/are to be used to load the files manually. The *load file* button can also be used to load diverse ASCII-files with varying naming.

Each window in the toolbox has a *graph tools panel* to manipulate the graphs. The desired graph can be selected from the dropdown menu *select graph*. With the *start* and *end* input-fields the desired time interval can be assigned. The user can also shift the graph to the right or to the left within assigned time intervals. This can be performed with the *show interval* input-field and the *forward* and *backward* buttons (see Fig. 3).

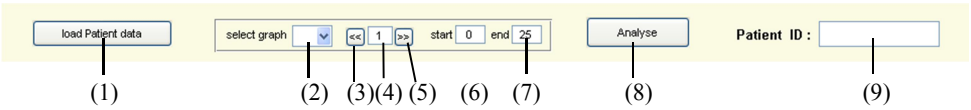

Fig. 3. Graph tools panel. (1) Load the patient's data button; (2) Select graph dropdown menu; (3) Backward button; (4) Show interval input-field; (5) Forward button; (6) Start time interval input-field; (7) End time interval input-field; (8) Analyse button; (9) Patient's ID input-field.

Analyse Button

The analysis is performed by activating the *Analyse* button: functions to analyse the data are run, the parameters are calculated from the data, and the resulting graphs and parameters are displayed.

Home, Print Save, and Exit Buttons

With the *Home* button the main window can be recalled to select and start another window. More than one window can be opened at the same time. The user can activate the *print* button to print a figure of the window (Fig. 4 (b), and (c)).

User can store the analysis results by the *save* button. Two files are generated and stored by this button. One is a bmp-image of the active window, and the second one is an ASCII-file which contains all the parameters calculated within the active window. In the windows for self-paced tapping analysis, two ASCII-files are stored, one for the right and one for the left limb.

Fig. 4. Common buttons of the analysis windows.

The user can quit the window by the *exit* button (Fig. 4. e). Before closing the window, a message is displayed to ask the user whether data are to be saved or not.

3. Synchronisation and Gait Analysis - Left/Right Windows

In the Synchronisation and Gait Analysis windows (Left/Right), eleven graphs are used. Five graphs are for representing the loaded data, three graphs to show the distribution of the angles values of the joints and three graphs for displaying the phase difference between them. Due to the large number of graphs and parameters in the gait analysis windows, it was decided to make two windows to analyze the movements of the left and the right side, respectively.

Fig. 5. shows the synchronization and gait analysis - Left window. The first and second row graphs display the loaded data. The third row graphs represent the distribution of the angles with the histogram and the extreme value distribution function (red curves). The bottommost graphs indicate the phase difference between the curves of the angles of the three joints.

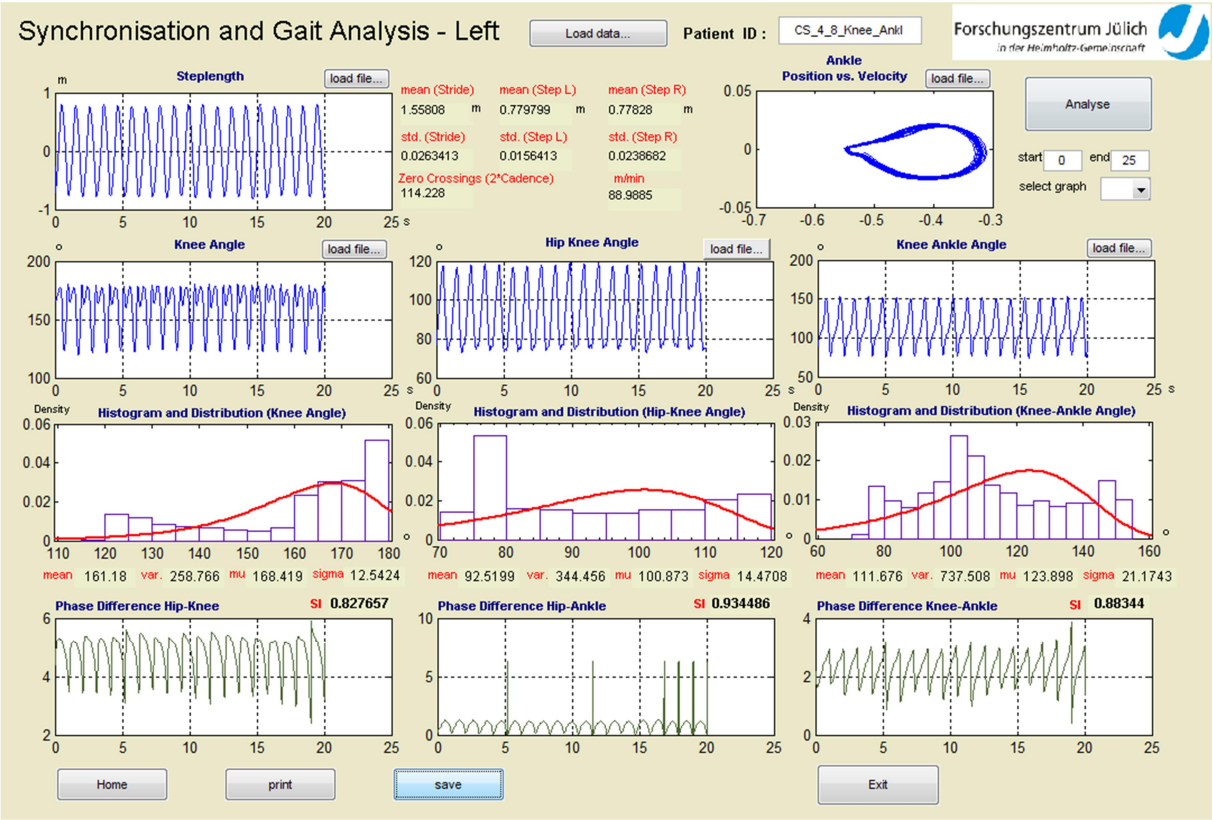

Fig. 5. The Synchronisation and Gait Analysis (Left) window as an example.

4. Self-paced Tapping – Forefoot/Heel/ Hand Windows

The self-paced tapping windows (i.e., for the forefeet, heels, and hands) have four graphs. Two graphs on the left side of the window for the left limb and two on the right side of the window for the right limb. The following statistics and parameters are provided: the averages of the instantaneous frequencies calculated separately based on the maxima and on the minima, average of tapping frequency (rate), the average amplitude of maxima and minima, standard deviation of the instantaneous frequency and the duration of the measurement.

Fig. 6 shows a self-paced tapping window (forefeet) as an example. The upper two graphs display the loaded data. In the graphs blue curves show the recorded movement, whereas the

red ones are the corresponding band-pass filtered signals. The lower two graphs show the instantaneous frequencies of tapping for the left and respectively the right forefoot.

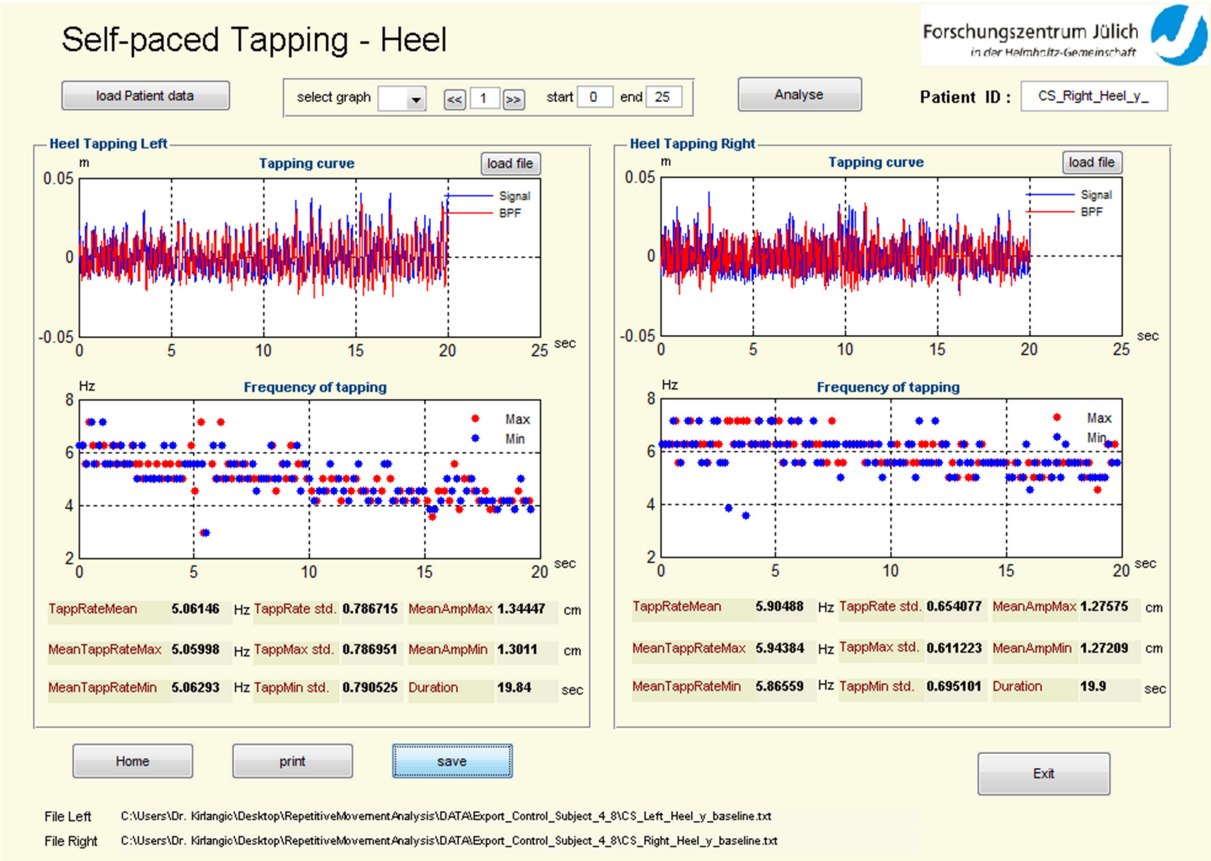

Fig. 6. Self-paced Tapping Analysis window (Heel).

5. Cued Tapping - Left/Right Windows

The cued tapping windows have five graphs. Two graphs to display the loaded data (top left and bottom right graphs) and three graphs to show the results of the analysis. The calculated parameters: maximal rising error, maximal falling error, the sum of the rising errors, the sum of the falling errors, root mean square of the errors and the duration of the measurement, are also presented.

Fig. 7. shows a cued tapping analysis window. The graphs on the left column are: 1) Tapping curve, 2) the time difference between the successive tones (blue curve) and the time difference between the detected successive tapping processes (red points), 3) the time difference between tone and the corresponding tapping response; on the right column 1) Instantaneous frequency of both the cueing tone (blue line) and the responding tapping (red line), 2) Position versus velocity of the hand.

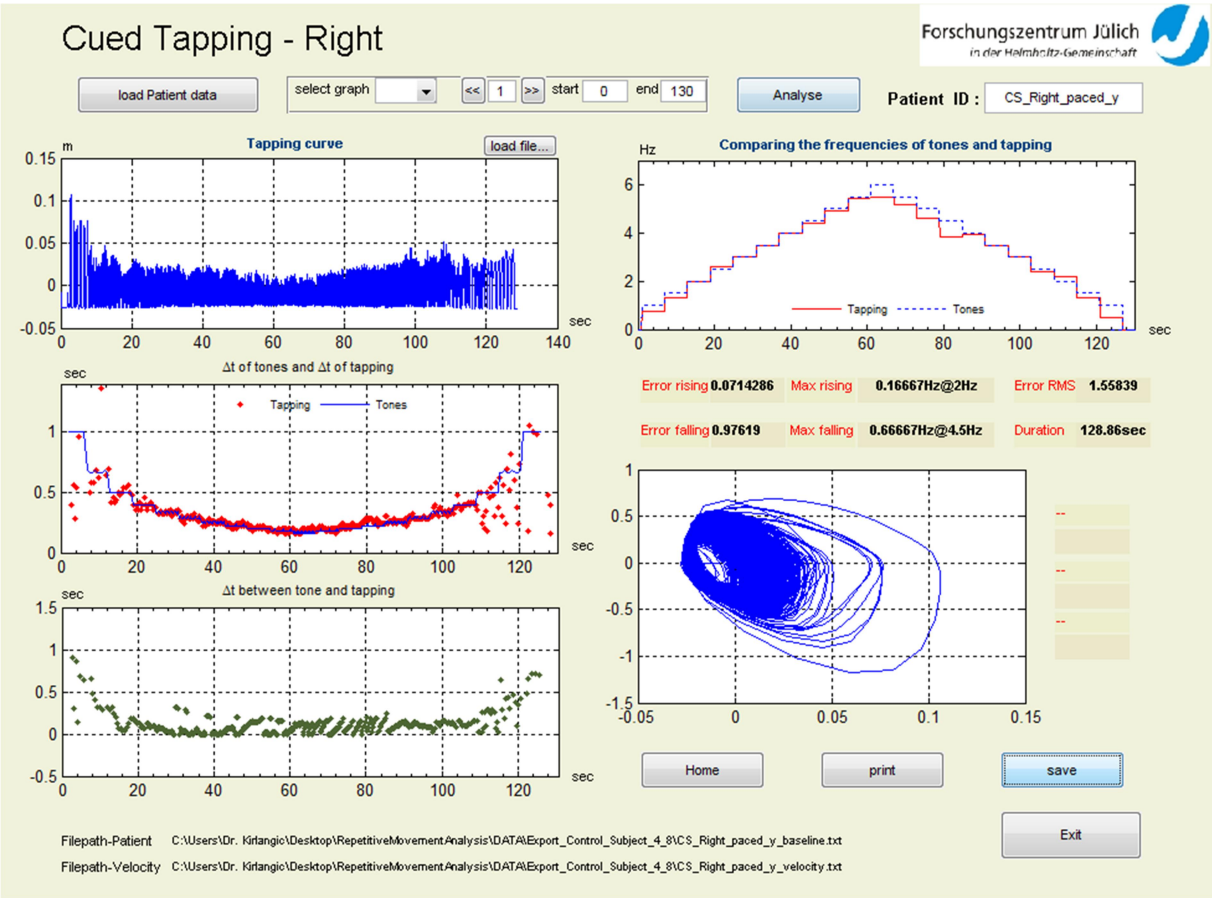

Fig. 7. Cued Tapping (Right) window.

6. Sample Data and Compulsory Files for the Analyses

Sample data are available under the following link: https://github.com/MehmetEylemKirlangic/DATA

The toolbox can be run either loading a *complete* set of data or alternatively loading specific files separately. Hence, other time-series from other recordings can also be analyzed. However, for an *automatized* analysis, following information, structure and file naming are required in the *complete* data set:

(a) Patient ID

In the clinical environment anonymization of patient data is required. Using the same Patient ID through diverse clinical systems simplifies data management. For the development of the toolbox, we used the assigned folder structure and file names based on the Patient ID (such as 10_96_27).

(b) Folder structure

For example, if the folder name is given as above, all the exported ASCII files from a measurement session (e.g, PreOP, PostOP etc.) are named accordingly e.g., Export_10_96_27_PraeOP.

(c) File names

The exported ASCII files are then named as following PatientID_PraeOP_Limb(compulsory)_Left/Right(compulsory)_PreprocessingStep(optional) _axis(optional)_parameter (optional).

(d) Files needed for each analysis:

1) Synchronisation and Gait Analysis (Left/Right) – 10 Files

i. Ankle position: Ankle_left/right
ii. Step length1: Step_Length_1 (Left)
iii. Step length2: Step_Length_2 (Right)
iv. Hip angle: Hip_left/right
v. Knee angle: Knee_Angle_left/right
vi. Knee ankle angle: Knee_Ankle_Angle_left/right

2) Self-paced Tapping Analysis (For each option two files: Left/right)

i. Left/right_Forefoot_baseline (position)
ii. Left/right_Heel_baseline (position)
iii. Left/right_Hand_baseline (position)

3) Cued Tapping Analysis (For each option two files _baseline and _velocity)

For cued tapping experiments the file name is expected to include the term "paced".

i. Left_paced_baseline; Left_paced_velocity
ii. Right_paced_baseline; Right_paced_velocity

4) Audio Signal

Audio signal trace from the video recordings is treated separately. It is saved under the file name *originalaudio*. The signal is down sampled by a factor of 50. The resampled audio signal is saved under the name *resampled*.

For the automatized analysis, if a novel file-naming is to be used/assigned, the related codes of the functions are to be modified accordingly.