# Python MU Editing User Manual

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This program can be used for the decomposition of HD-EMG signals. After the decomposition, the motor units are visualized and manual editing can be applied. This program and manual are based on the open-source MUEdit Matlab program [1, 2].

## 1 When and why to use

Manual editing is a crucial step in the motor unit decomposition process. Since the decomposition algorithm is not flawless, each motor unit must be visually reviewed after the decomposition. It is up to the user to determine whether any edits are necessary [2]. To get an idea of the effect editing can have on the discharge rate plot, see figure 1.

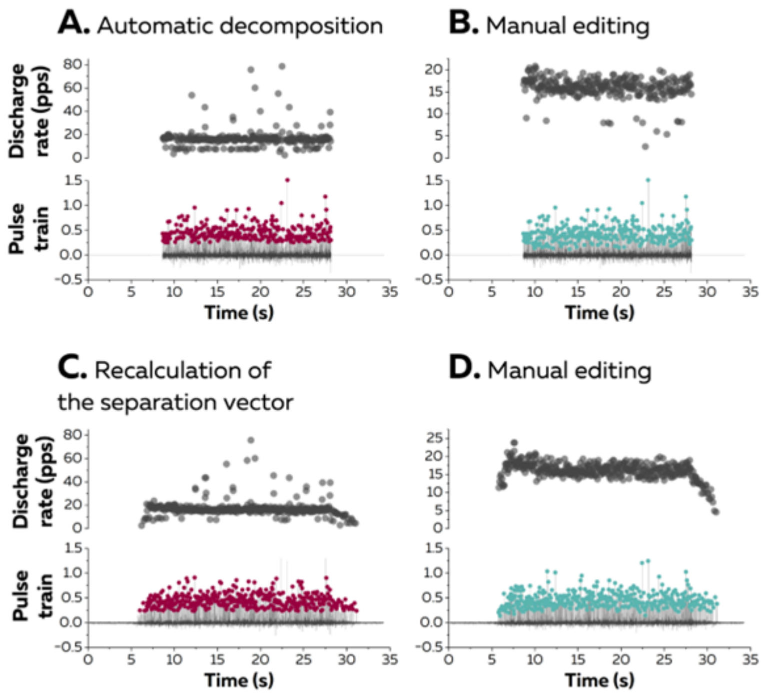



Figure 1: Effect of motor unit editing. In A. the before is seen. In B. the outliers at the top are removed. In C. the filter is recalculated. In D. the final result is shown after a couple of iterations of editing and recalculating. As can be seen, the discharge plot is much smoother than in A. [2].

## 2 How to use

### 2.1 Installation

Firstly, the program must be installed as explained in the Readme file of the repository.

### 2.2 Load data

Currently, the supported data types are:

- .poly5 files for decomposition mode. This file, preferably with force reference signal, should be a training file where a trapezoidal force profile is followed.
- OpenHDEMG style .json files for editing mode.

To switch between modes, edit the `MODE` variable in the main file. Only data from 1 HD-EMG grid is supported at this time.

### 2.3 The GUI

When a decomposed file is loaded, the GUI will appear (see figure 2). The plot at the top shows the instantaneous discharge rates, which has been calculated by using the time between two consecutive firings, along with the silhouette value of the current pulse train. The plot at the bottom shows the pulse train with detected peaks, as well as the number of the current motor unit on the left. The force profile is overlayed in grey.

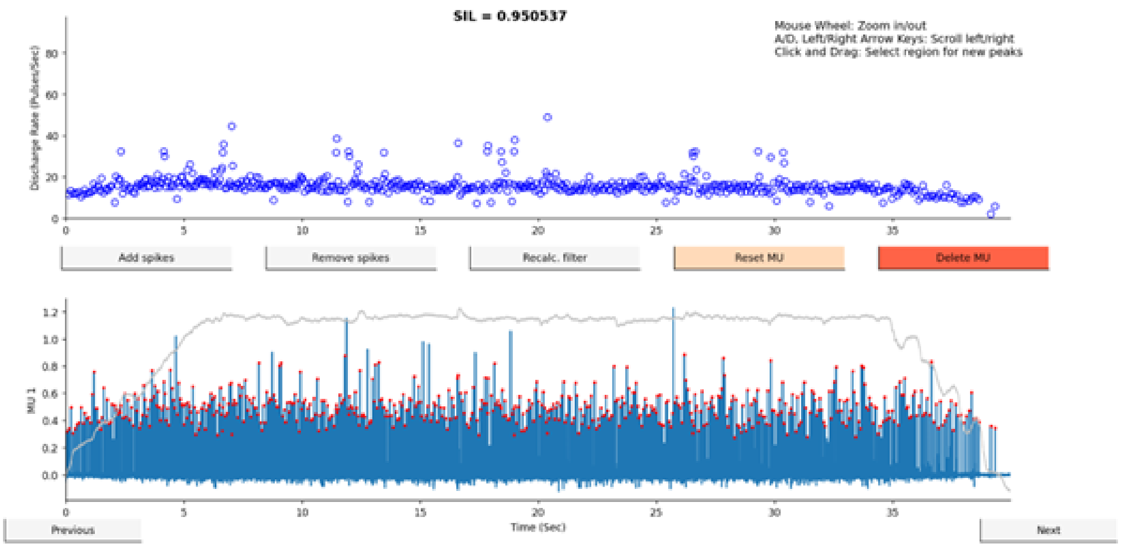



Figure 2: GUI of the software.

Multiple buttons can be pressed in the GUI:

- **Previous/next:** Navigate to previous/next motor unit
- **Add/remove spikes:** Enables a rectangle selector in the bottom plot. Selecting a peak will add or remove it from the list of peaks, and the discharge rate in the top plot will update accordingly.

- **Recalc. filter:** Recalculates the motor unit filter for the current motor unit. Only the current window is affected; the pulse train and discharges outside of this window are unaffected.
- **Reset MU:** Resets the current motor unit to its original state. Use this if editing does not produce the desired result.
- **Delete MU:** Deletes the current motor unit if deemed unreliable by the user.
- **Zooming/scrolling:** Use the mouse wheel or arrow keys to zoom/scroll.

### 2.4 Editing

To edit a motor unit, follow these steps in order [2, 3, 4]:

1. **Identify a window of about 3 seconds containing false positives.** A good way to do this is by observing the discharge rate in the top plot. If there are clear peaks (more than double the discharge rate of the surrounding discharges), the algorithm likely added a peak incorrectly. Advisable is to start with the highest peaks in the discharge rate plot, as removing these will scale the y-axis to give better detail.
2. **Remove low quality spikes.** In this window, remove all low-quality spikes using the "Remove spikes" button, then press the "Recalculate filter" button. If unwanted spikes remain, repeat the process. You can experiment with window size if the filter is not recalculating as intended. Smaller window size results in the peak (de)selection having more of an impact, usually at the cost of a lower silhouette value.
3. **Repeat for all windows of interest** until no false positives remain.
4. **Repeat step 1-3, but now for false negatives**, i.e. peaks that incorrectly have not been selected. Again, this can be made easier by looking for valleys in the top plot of discharge rates. Larger window sizes can usually be chosen for the false negatives, resulting in less of a silhouette penalty per recalculation.
5. **Check silhouette value.** If after edition the silhouette value has not increased and is not well above 0.9, delete the MU or reset the MU and try again.
6. **Repeat this process for all motor units.**

After editing, the discharge rate plot of all identified motor units should look smooth, without significant peaks/valleys, as in figure 1D. To note: removing or adding a peak is always followed by pressing the 'Recalc. filter button' to avoid bias, **never** add/remove peaks without recalculating.

To save the edition, simply close the GUI and the file will be saved in your measurements folder with '_edited' appended. The file is an OpenHDEMG style .json file.
As this file type can be used as an input, you can continue editing where you left off by loading this file.

### 2.5 Decomposition

Above workflow is for when a .json file is loaded with the decomposition part already finished. However, the software is also capable of doing this decomposition.
By running the program in 'decompose' mode and selecting a .poly5 file from the measurements folder, the decomposition will start.

First, the EMG signal channels are shown. Here you can deselect channels based on signal quality by clicking on the channel names of the channels you want to leave out of the decomposition.

There are multiple parameters to adjust in this program:

- **Rejected channels:** This parameter determines which channels do not get taken into account during the decomposition. You can reject channels in the GUI that shows up after selecting your file.
- **To filter:** You can adjust this parameter depending on whether your EMG signal has been filtered or not. To do this, in the init function of `EMG_Decomposition.py` set either a 0 or a 1 where the `offline_EMG` class is instantiated.
- **Additional parameters** in the init function in `EMG_classes.py`:
  - **Number of iterations** of the BSS algorithm
  - **Number of extended channels** used in the algorithm
  - **Duplicate threshold:** value between 0-1 which represent percentage of firings that need to overlap for the algorithm to register two motor units as duplicates
  - **Covariance threshold:** Threshold that determines below what value the covariance of interspike intervals has to be for the filter to be accepted. Only works if the covariance filter parameter has been set to 1.
  - **Silhouette threshold:** Threshold that determines above what value the silhouette value has to be for the filter to be accepted
  - **Other parameters:** There are more parameters representing different functionalities of MUEdit in Matlab, but a lot of these have a TO-DO next to them saying they are untested. Advisable is to leave these as they are for now.

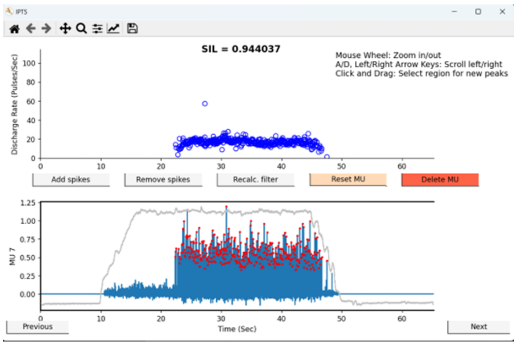
After the decomposition, the file will be saved in your measurements folder with '_decomp' appended and the program will go into editing mode.

## 3 Examples

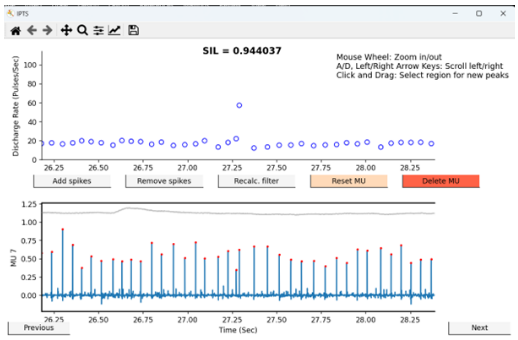
For reference, examples of how (not to) to use the software are included. Of note, given the same decomposed data and basic instructions, operators with varying amounts of experience converge toward almost identical motor unit spike trains most of the time [4].

### 3.1 Correct Example

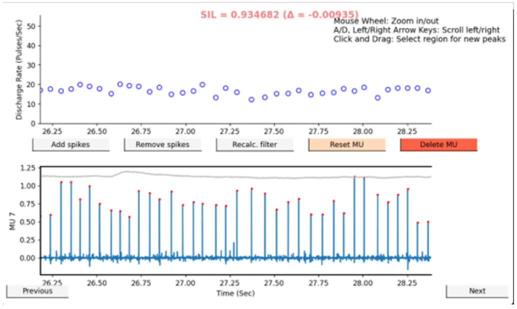
See below in figure 3 an example of how the editing process looks, following the steps in section 2.4.



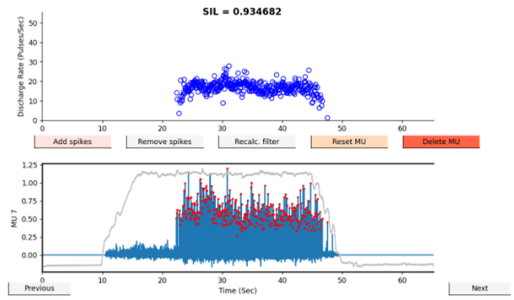

(a) The spike train before editing, an incorrectly identified peak can clearly be spotted in the discharge rate plot.




(b) Zooming in, the incorrect discharge is identified.




(c) Removing this peak and pressing the 'Recalc. filter' button gives the recalculated pulse train for this window




(d) Zooming out again, the discharge plot looks a lot smoother

Figure 3: Example of correct pulse train editing. The SIL value has dropped due to the editing. But since this is still above 0.9 the edit is accepted.

## 3.2 Incorrect Example

Looking at the same pulse train as above, see figure 4 for a wrong edition. This example shows the importance of zooming into the region of interest to ensure the manual edition has the desired effect on the pulse train. Since the edition lowered the SIL value without improving the discharge rate plot, the motor unit should be reset and the user has to try again.

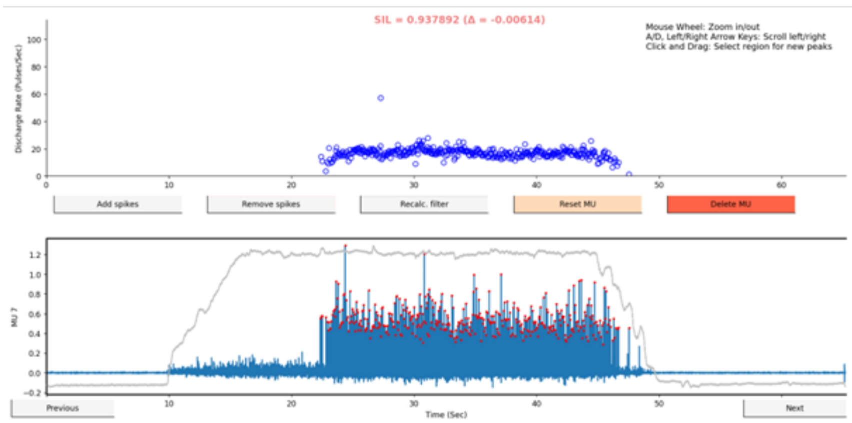



Figure 4: When the same spike is removed from the dataset, and the 'Recalc. filter' button is pressed in a larger window, the peak is not removed by the algorithm.

### 3.3 Unreliable Motor Unit Examples

See figure 5 for an unreliable motor unit. The discharges have big gaps between them while the force remains constant and the motor unit is not firing throughout the whole steady state of the force graph. Seeing this, the motor unit can be deleted.

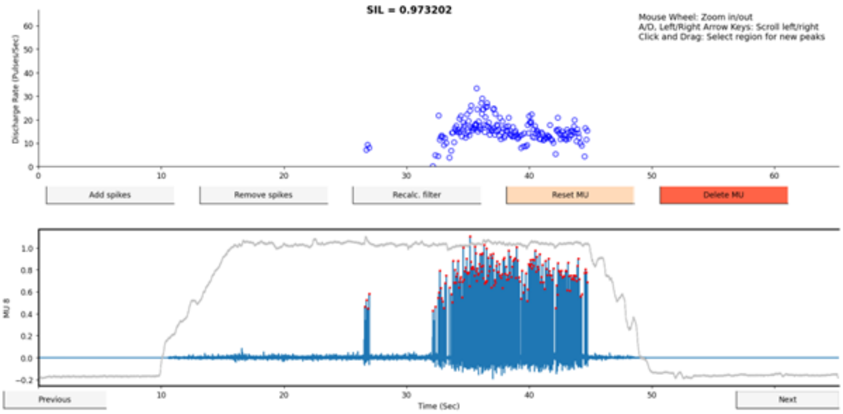



Figure 5: Example of an unreliable motor unit

Another example of this is a motor unit that has so much editing that needs to be done, that the SIL value drops too low. See figure 6, where the SIL value drops way below 0.9, making the motor unit unreliable. The motor unit has to be deleted, or the editing has to start over using the reset button.

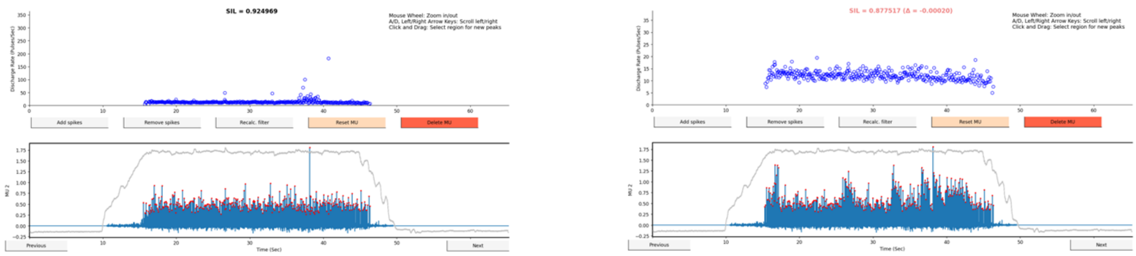


Figure 6: In the left discharge plot, you can already see the plot is very erratic. In the right plot, you see the edited version. So many edits had to be made that the SIL value dropped way below 0.9, making the motor unit unreliable.

## References

[1] Simon Avrillon and Michael Uren Hub. *MUedit: a step-by-step user manual*. 2024.

[2] Simon Avrillon et al. "Tutorial on MUedit: An open-source software for identifying and analysing the discharge timing of motor units from electromyographic signals". In: *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology* 77 (Aug. 2024). ISSN: 1873-5711. DOI: 10.1016/J.JELEKIN.2024.102886. URL: https://pubmed.ncbi.nlm.nih.gov/38761514/.

[3] A. Del Vecchio et al. "Tutorial: Analysis of motor unit discharge characteristics from high-density surface EMG signals". In: *Journal of Electromyography and Kinesiology* 53 (Aug. 2020), p. 102426. ISSN: 1050-6411. DOI: 10.1016/J.JELEKIN.2020.102426.

[4] François Hug et al. "Analysis of motor unit spike trains estimated from high-density surface electromyography is highly reliable across operators". In: *Journal of Electromyography and Kinesiology* 58 (June 2021), p. 102548. ISSN: 1050-6411. DOI: 10.1016/J.JELEKIN.2021.102548.