TMS ioFit

User's Guide

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About TMS ioFit

TMS ioFit is a Matlab toolbox, for fast and optimal estimation of neural recruitment input-output (IO) curve and parameters in transcranial magnetic stimulation. Interested readers are directed to [1] for details about the algorithm and its performance. This manual describes the setup and use of this toolbox.

Copyright statement & How to cite this manual

Warranty

Acknowledgment

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Tables of Contents

1. Test Procedure

STEP 0: **Save the toolbox in a folder.**

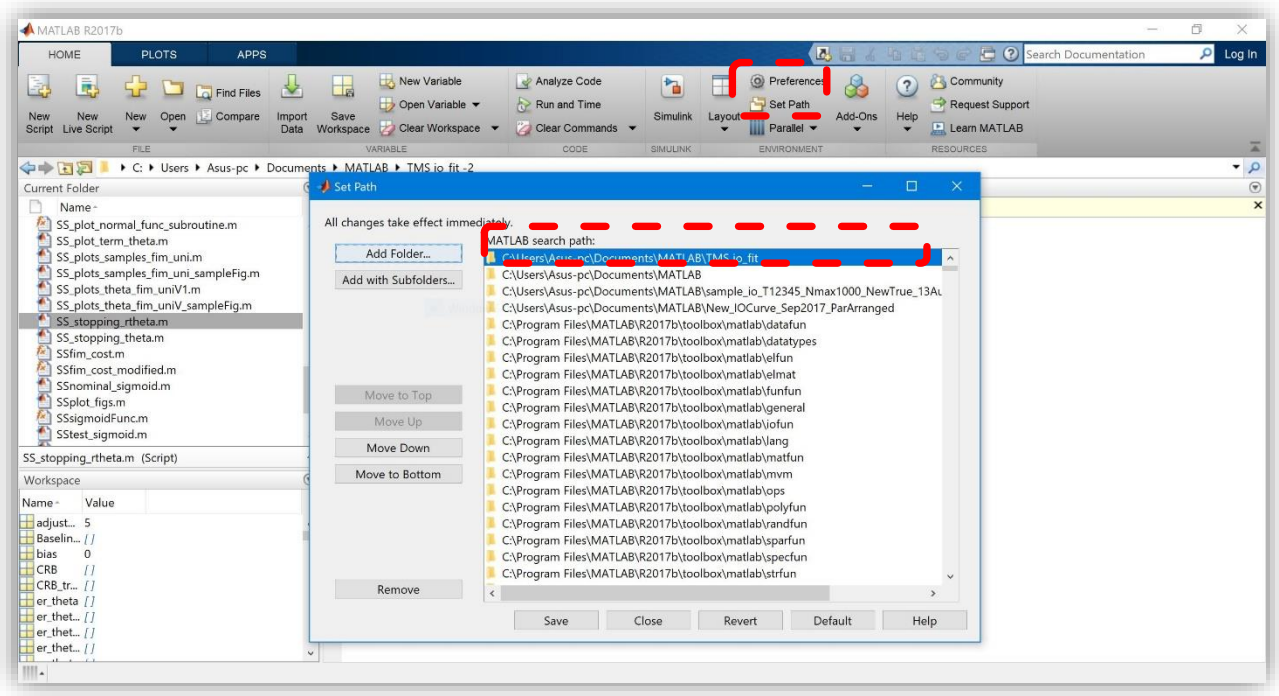
STEP 1: **Run Matlab.**

In WINDOWS: Go to Start, find Matlab and run it.

In Mac: Start it from the Matlab icon in the dock or in the application folder.

STEP 2: **Set path.**

Click on the set path icon, shown in the following figure, and save the path of the folder.



STEP 3: **Write down *TMS_LAB* in the workspace.**

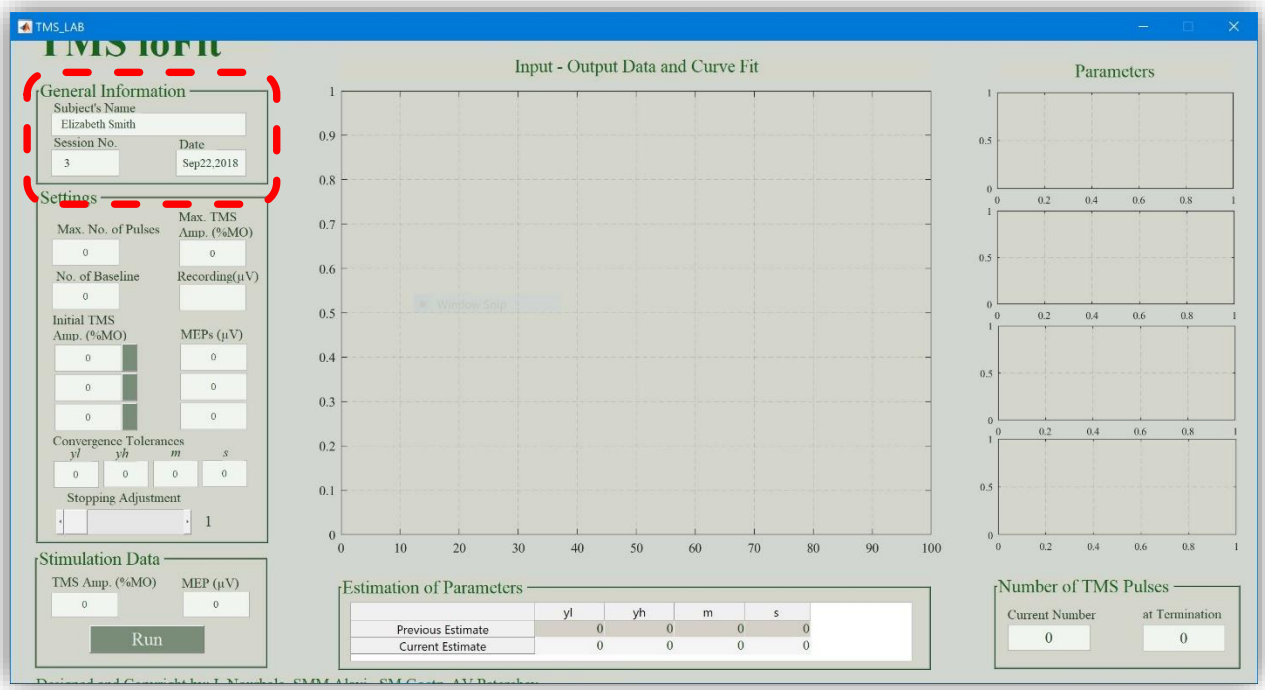
The TMS ioFit graphical user interface (GUI), shown in the following figure, pops up.

STEP 4: **Enter the subject's general information.**

Subject's name

Date of session

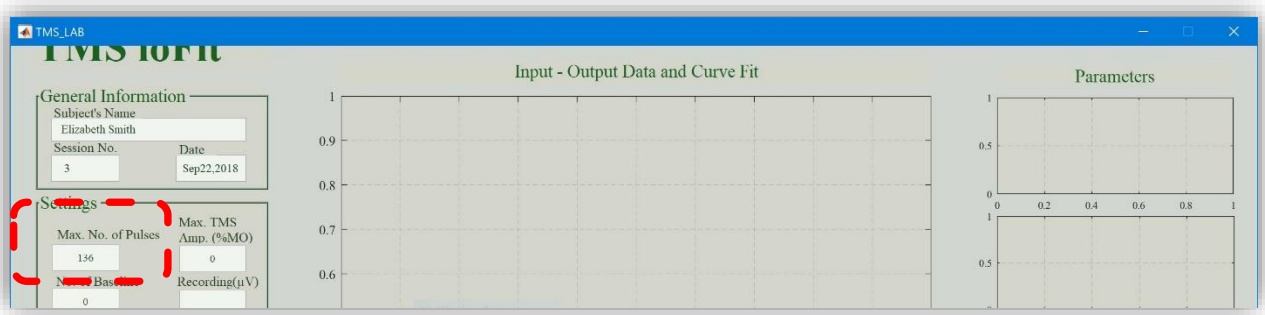
Number of sessions



STEP 5: **Enter the maximum number of TMS pulses for (IO) curve estimation.**

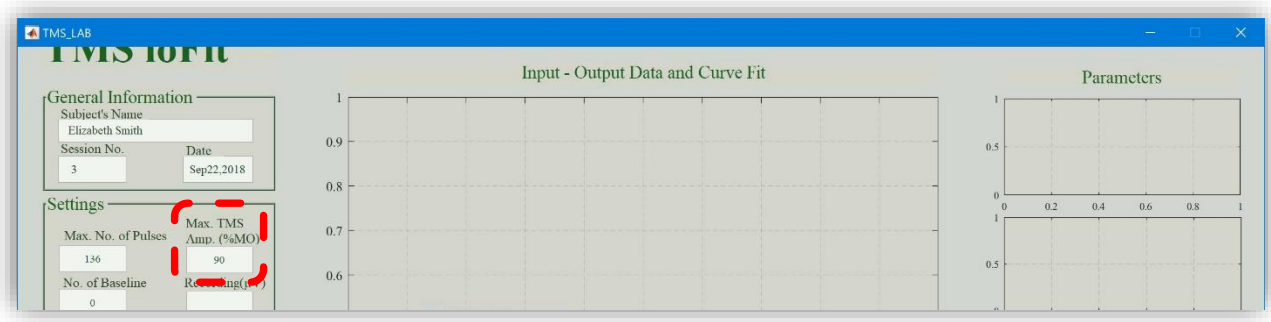
The estimation will stop if stopping rule is not satisfied with this number of pulses.

By using the model in [2], it was shown over more than 10,000 tests that the proposed IO curve estimation method converges with the median of about 80-90 pulses, [1]. By adding a tolerance to it, the default value is set to 150 maximum pulses if no data is entered.



STEP 6: **Enter the maximum amplitude of applied TMS pulses.**

This is a maximum TMS power that a subject can tolerate. The default value is 100% if no data is entered.



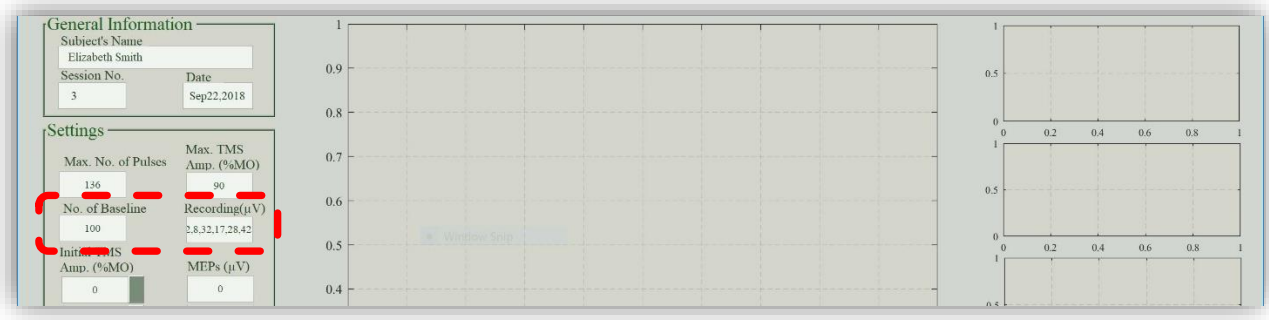
STEP 7: **Enter the baseline data.**

Baseline data represents the measurement noise, and is the EMG recoding in the absence of TMS pulses (x=0). Enter the baseline data as:

1e-5, 0.9e-5, 1.2e-5, 0.000008

Then, press Enter key. The number of baseline data is automatically written in the adjacent text box.

There is no specific rule for the determination of the number of baseline data. The larger the better. In the closed-loop TMS, the baseline data can automatically be recorded by a high speed data acquisition system.

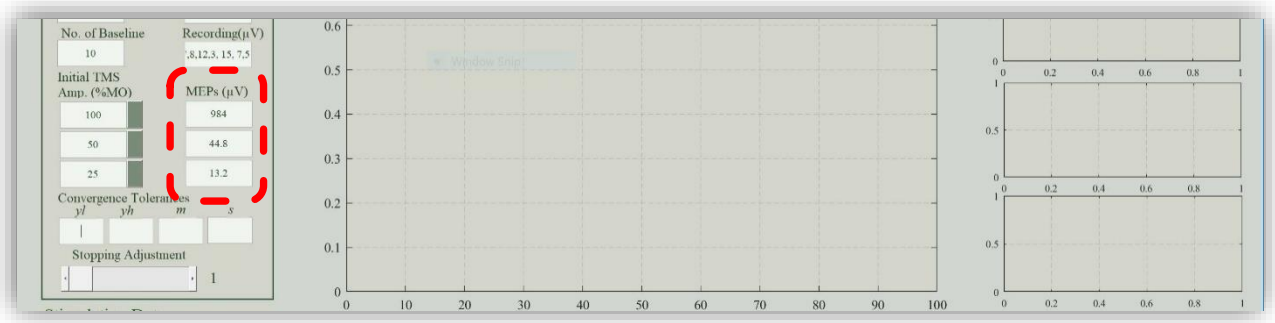


STEP 8: **Apply the first three TMS pulses and enter the corresponding MEP.**

In order to start, TMS ioFit requires three initial TMS pulses. The amplitude of these values can be random. Note that the power of pulses does not exceed the one that the subject can tolerate.

By clicking on the push-buttons, shown in the following Figure, 25%, 50% and 100% of the maximum power are chosen as the initial pulse amplitude.

By applying each TMS pulse, enter the corresponding EMG value in μV. For instance, if the EMG recording is 0.00005(V), enter 50(μV).

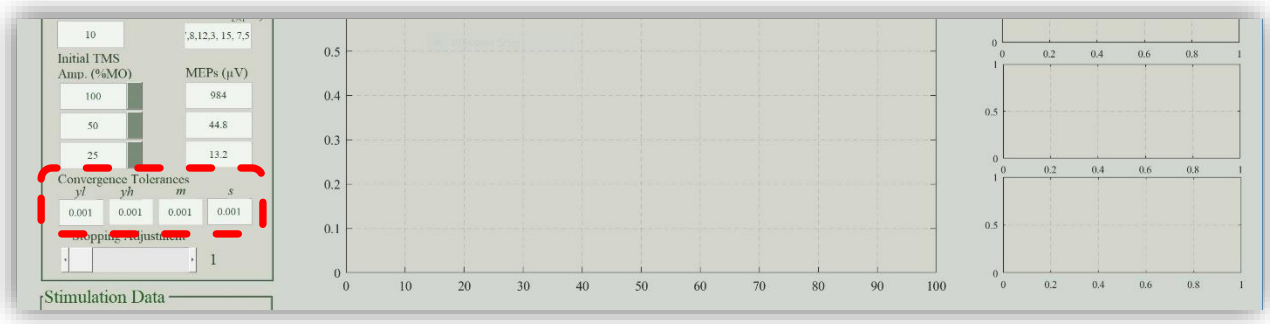


STEP 9: **Enter the convergence tolerances.**

TMS ioFit stops estimation if a stopping rule is satisfied, or if maximum numbers of pulses are taken without satisfaction of the stopping rule. Stopping rule is met if the converge criterion

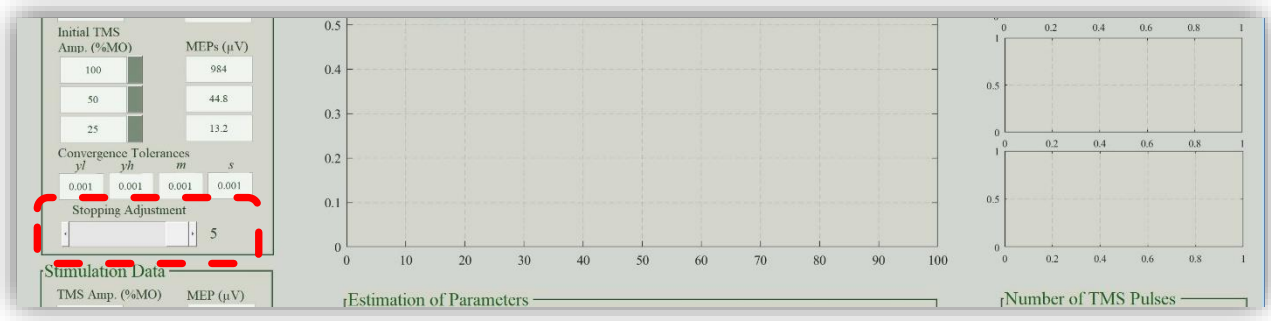
$$\left|\frac{\theta_n - \theta_{n-1}}{\theta_{n-1}}\right| < \varepsilon$$

is satisfied for a number of successive times for all parameters. $\varepsilon = [\varepsilon_1\ \varepsilon_2\ \varepsilon_3\ \varepsilon_4]$ denotes the convergence tolerance. The default value is set to 0.01, for all parameters, if no data is entered.



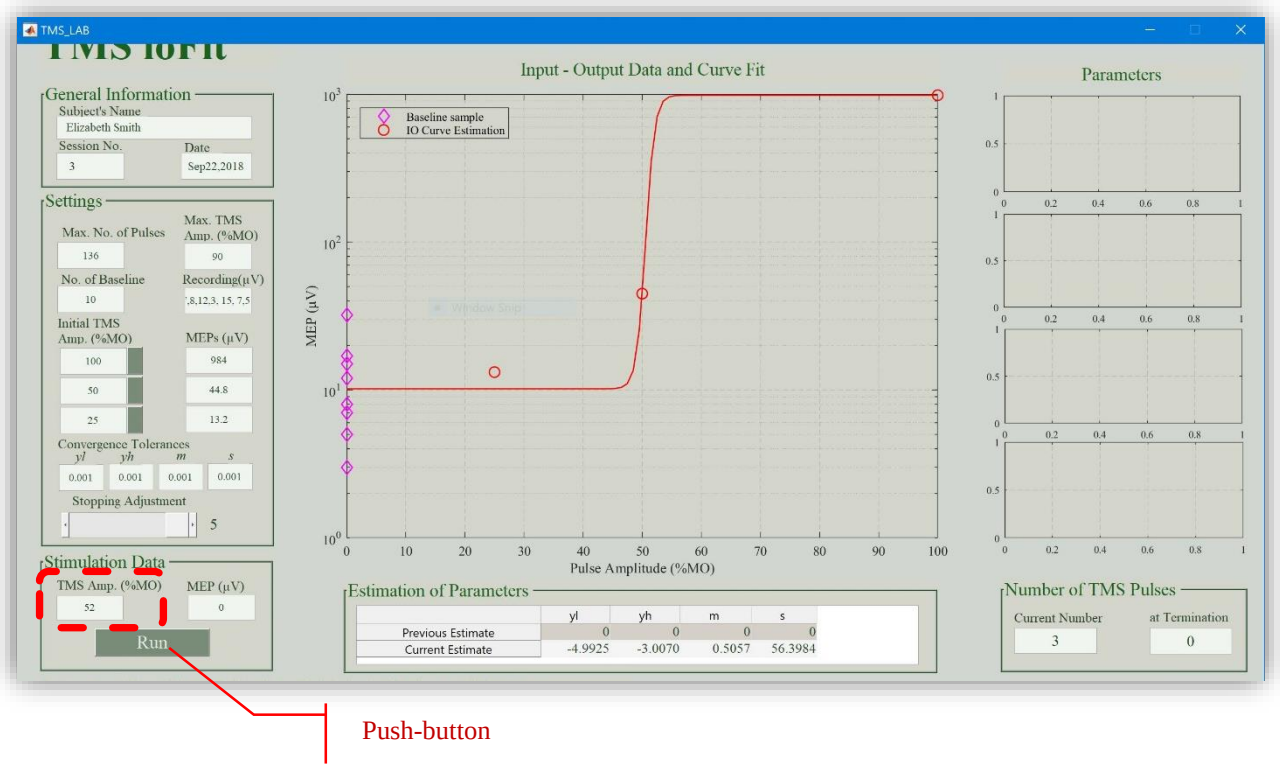
STEP 10: **Adjust the stopping rule for termination.**

Stopping adjustment is the number of successive times that the convergence criterion is met before termination. Stopping adjustment is performed by using the tool shown in the following figure. The number set by the user is written next to the sidebar. The default value is set to 5, as the larger this number, the better estimation error is achieved [1].



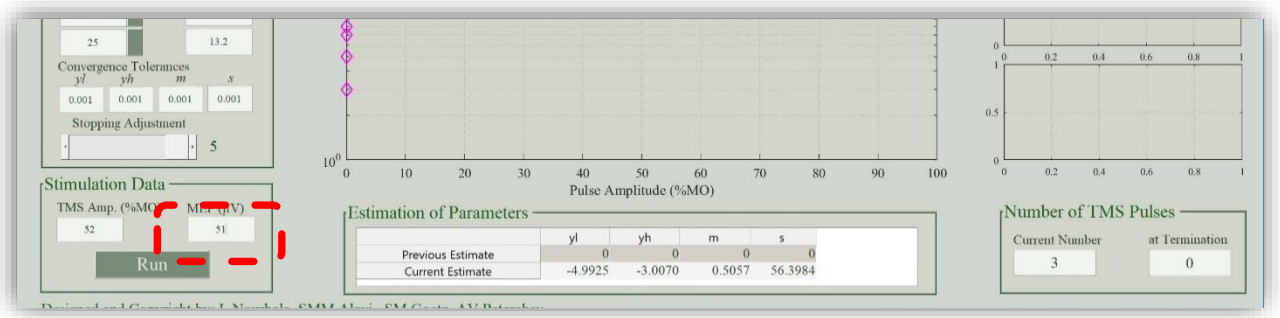
STEP 11: **Get the first estimation and 4th TMS pulse.**

After the above steps, press on the *Run* push-button. An initial estimate of the IO curve is then computed. The magnitude of the next TMS pulse that operator should apply on the subject is also computed and appears in the box shown in the following figure.



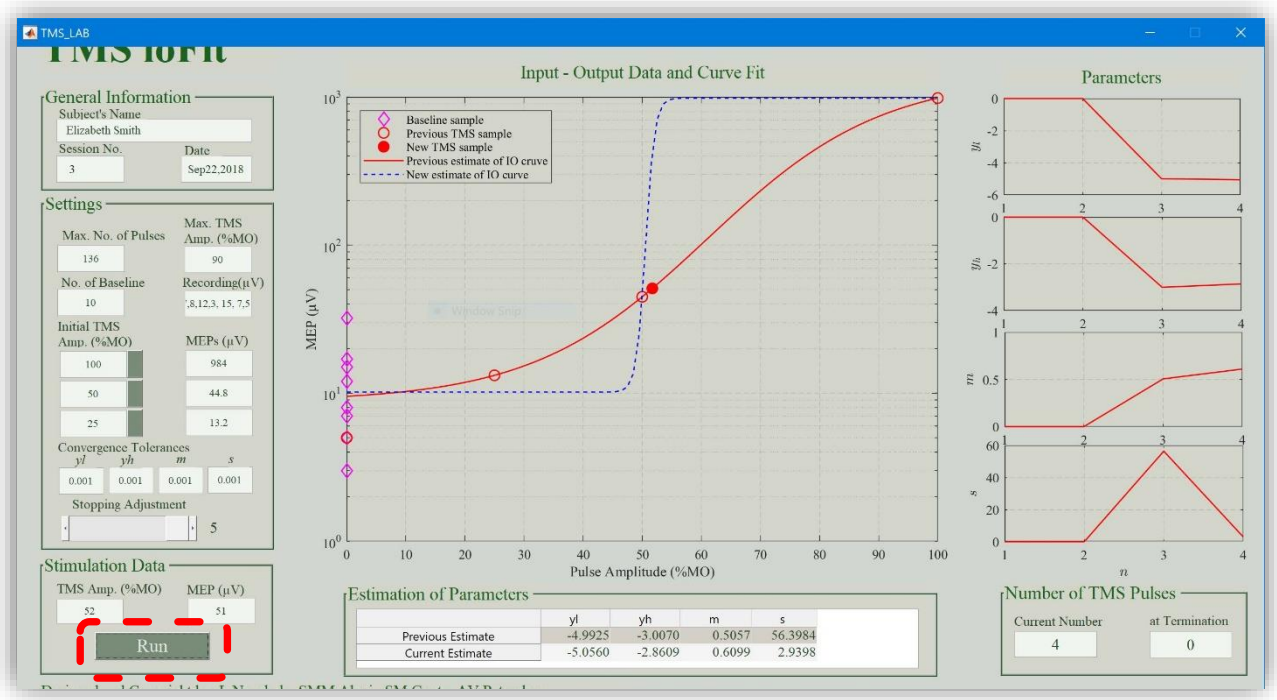
STEP 12: **Enter the MEP.**

Apply the TMS pulse, and enter the corresponding MEP in the box, shown in the following figure.



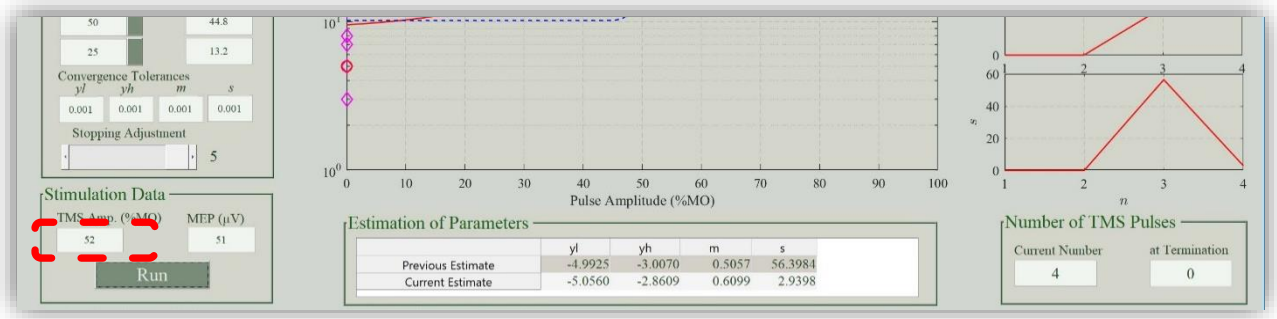
STEP 13: **Press on the *Run* push-button to estimate IO curve and parameters.**

By pressing the Run push-button, a new estimate of the IO curve and parameters is computed and plotted in the figure boxes.



STEP 14: **Press on the Run push-button again to compute the next TMs pulse.**

Press on the *Run* push-button again to compute the amplitude of the next TMS pulse that operator should apply on the subject. The value is given in the text box, shown in the following Figure. Then, go to Step12 and repeat the process until termination.

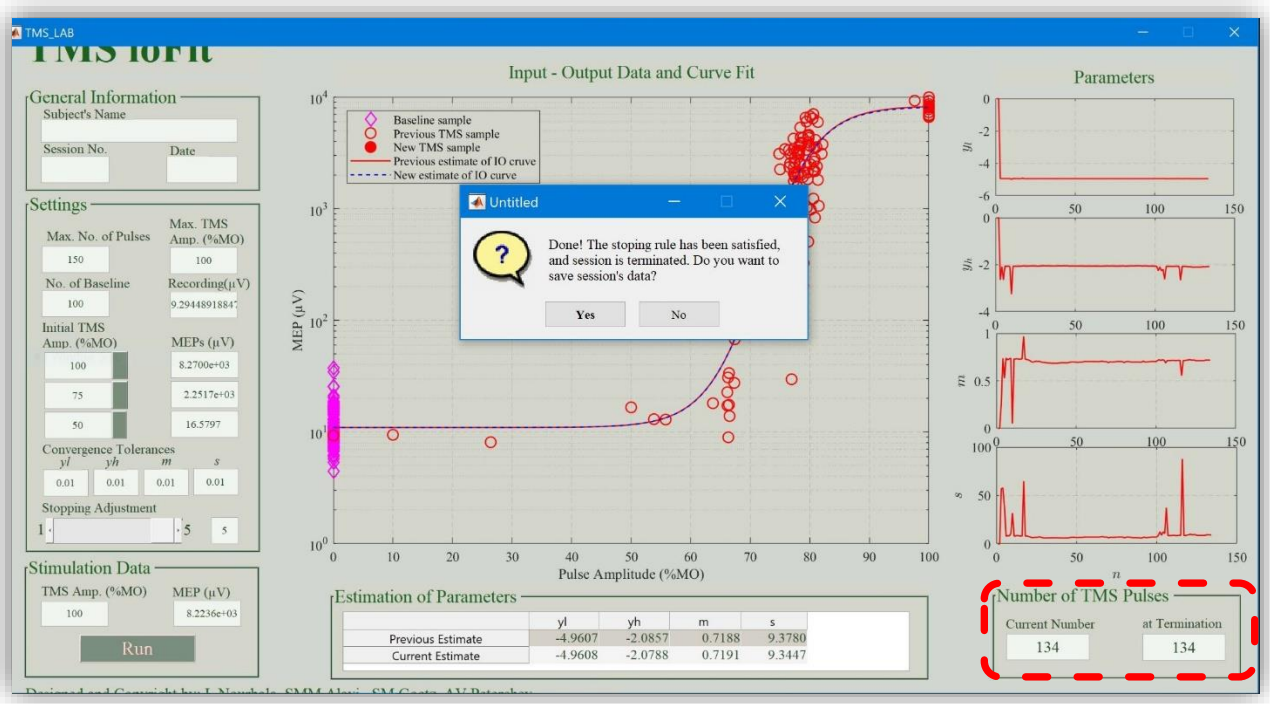


STEP 15: Termination

If stopping rule is satisfied.

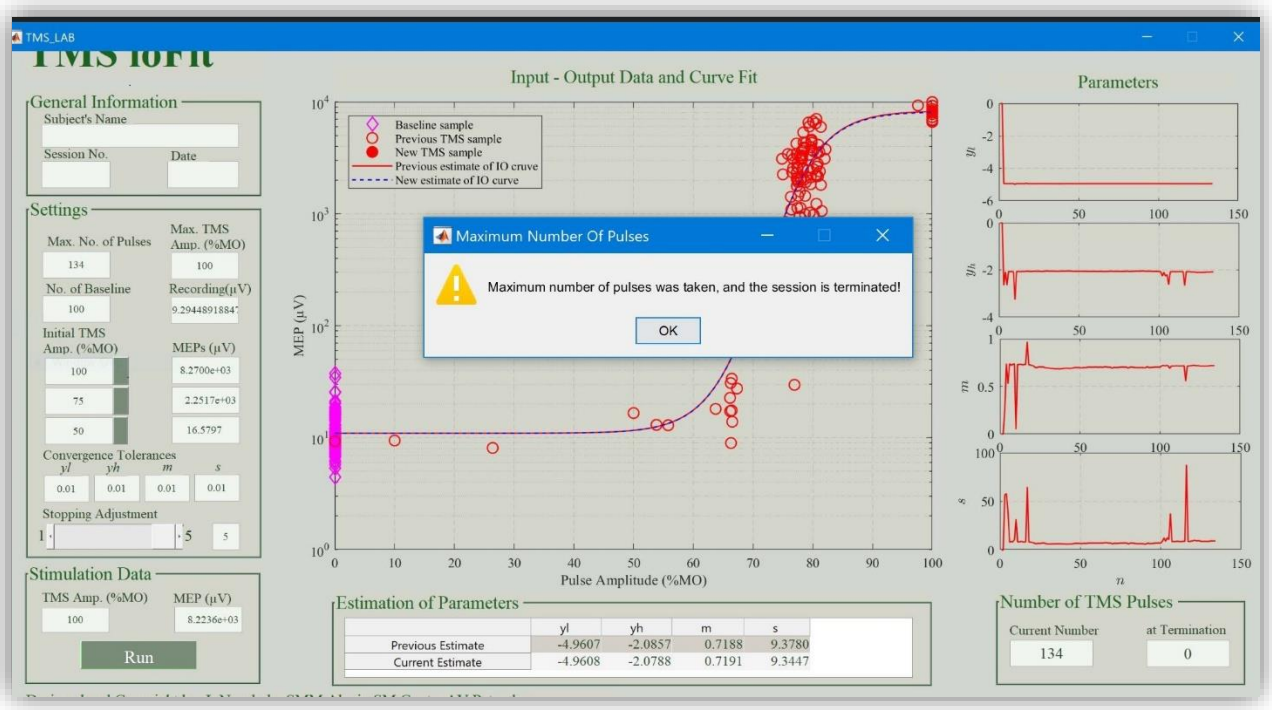
When termination occurs, the number of pulses at which the estimation satisfies the stopping rule is displayed in the right box shown in the following Figure. The left box in this panel shows the current number of TMS pulses.

After satisfaction of stopping rule, the question dialog box pops up automatically for data saving.



If maximum number of pulses are taken and stopping rule is not satisfied:

In this case, a dialog box pops up automatically. Even in this case, you can save the session's data by using File → Save → Session's Data



STEP 16: Save Data

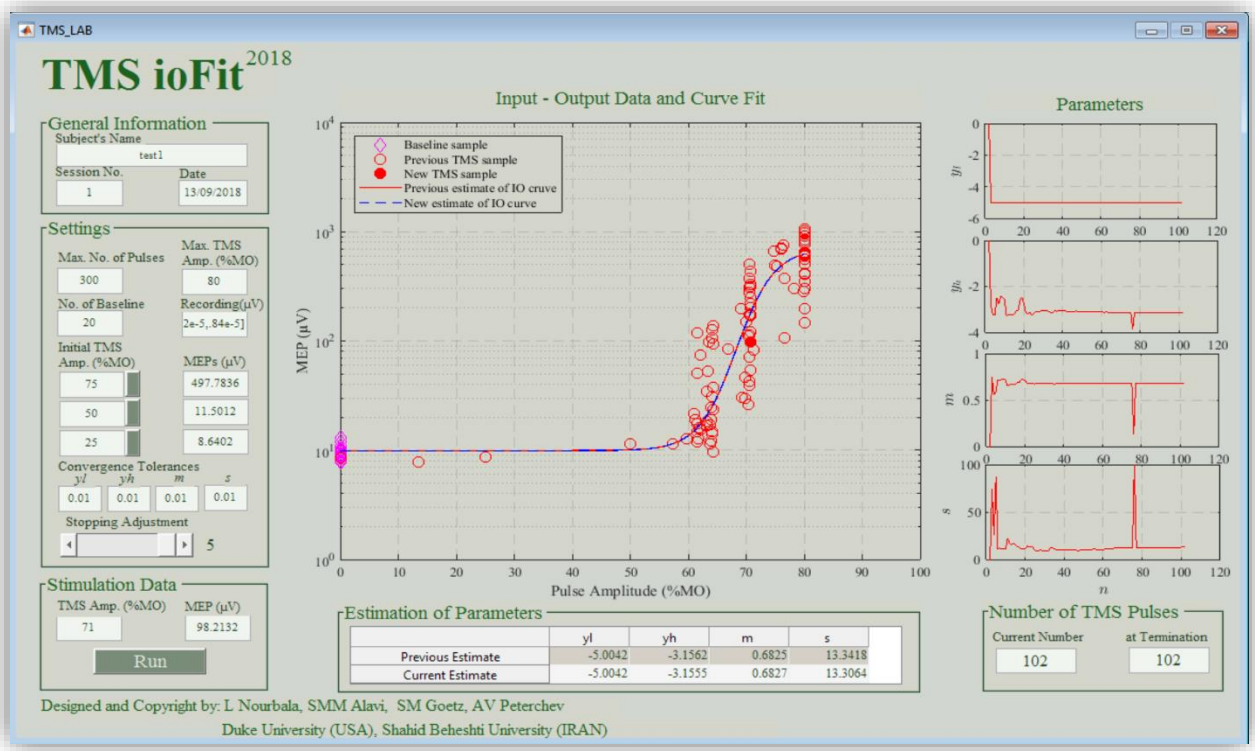
After satisfaction of stopping rule, the question dialog box pops up automatically for data saving.

The session's data can be saved any time by using File → Save → session's data

The session's data is saved in *.xlsx format. The *.fig format of input-output curve, lower plateau, higher plateau, midpoint and slope can also be saved from File → Save.

2. Results of a Representative Run

The Following figure shows the results of a representative run. The MEP data was generated by using the model in [2]. Estimation was terminated after applying 120 TMS pulses. The central figure shows the IO curve fit (the current estimate as well as the one before it). It is seen that the proposed method takes mainly samples from three most important areas of the IO curve to estimate the slope and upper plateau. The figures on the right side show the estimations of the IO curve parameters, i.e., y_l, y_h, m, and s, versus the number of TMS pulses. Numerical estimates of the IO curve parameters appear in the table below the central figure.



3. References

[1] SMM Alavi, SM Goetz, AV Peterchev, " Optimal Estimation of Neural Recruitment Curves Using Fisher Information", Under Review, 2018.

[2] SM Goetz, SMM Alavi, Z-D Deng, AV Peterchev, Statistical Model of Motor Evoked Potentials for Simulation of Transcranial Magnetic and Electric Stimulation, bioRxiv 406777, 2018.