Profilometer GUI Help Document

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1 Introduction

I have worked extensively with a Tencor AlphaStep 200 profilometer during my course of studies at Brigham Young University. My project reached a point where I needed to store several consecutive profilometer scans to later analyze. My first meager attempts at this resulted in writing down each value on the profilometer screen by hand. This proved to be extremely tedious, and thus began the quest to interface a computer with the profilometer. This task was achieved through the work and help of Lynnell Wright and Brian Phillips, who first discovered how to set the "print" mode on the profilometer to correspond to a digital data transfer instead of a physical printout.

Many thanks must also be attributed to Matthew A. Hopcroft at the University of California, Berkeley, who provided a Matlab script that interprets and plots profile data that has been captured by a hyperterminal program. He also provided the insight into setting the jumper cable on the profilometer CPU board so that digital data could be transferred via a serial cable. He has provided a very robust program along with detailed instructions at http://micromachine.stanford.edu/ hopcroft/Shared/profilometer.html.

Through the course of my research, however, I found that I was spending a lot of time writing unique Matlab scripts for every set of data I was analyzing, and my thoughts turned to creating a graphical method for allowing ease of selecting and saving specific data points. This led to creating a graphical user interface (GUI) in Matlab that allowed for high-level profilometer data manipulation. This program is capable of reading in scanned data directly from the profilometer without having to implement a separate hyperterminal program. Data can also be read in from text files that have been previously saved. Once the data is read in, it can be leveled, set to a zero point, and reset. Altered profiles can then be saved out to a text file. This program also allows directly saving the plot as an image with various options. This program also allows a user to record several data points into one file to later be plotted and analyzed. These capabilities are outlined in the table of contents of this document, and will be explained in detail.

As of this writing, *Profilometer GUI* is still in its alpha stage (0.1), and as such there undoubtedly will be errors or strange behavior beyond what I have accounted for. In the case that you find any errors (lucky you), please, to the best of your ability, outline the circumstances leading to the problem and contact me at marknhamblin@gmail.com and I will attempt to address the issue. Good luck with using the graphical interface, and I hope that it facilitates your research.

2 Getting started

The file *profilometerGUI.m* is a script file that must be run using Matlab. This script was created using Matlab 7 (R14), so any version of Matlab that is seven or higher should work. In order to run the program, simply double-click the file name or open the file name inside of Matlab.

If the file loads successfully, you will see a screen that looks similar to Figure 1. The numbers added to the screen indicate the main features of the program:

1. File menu for scanning, loading, or saving data
2. Edit menu for leveling, zeroing, or reseting data
3. Analyze menu for concatenating data sets
4. Help menu for help document and information about the program
5. Screen where profile image will appear
6. Button to read in scanned data from the profilometer
7. Screen indicating current scan status
8. Button to level data on the screen
9. Button to set a zero point for data on the screen
10. Button to reset the data on the screen
11. Button to capture the selected data points on the screen and add them to a running list
12. Displays the position of the left bar
13. Displays the profile height at the left bar
14. Displays the position of the right bar
15. Displays the profile height at the right bar

16. Displays the spacing between the bars
17. Displays the height difference between the points at the bars
18. Check box that will cause the spacing between the bars to be locked
19. Displays the average height between the bars
20. Displays the deviation of height between the bars
21. Displays the surface roughness between the bars

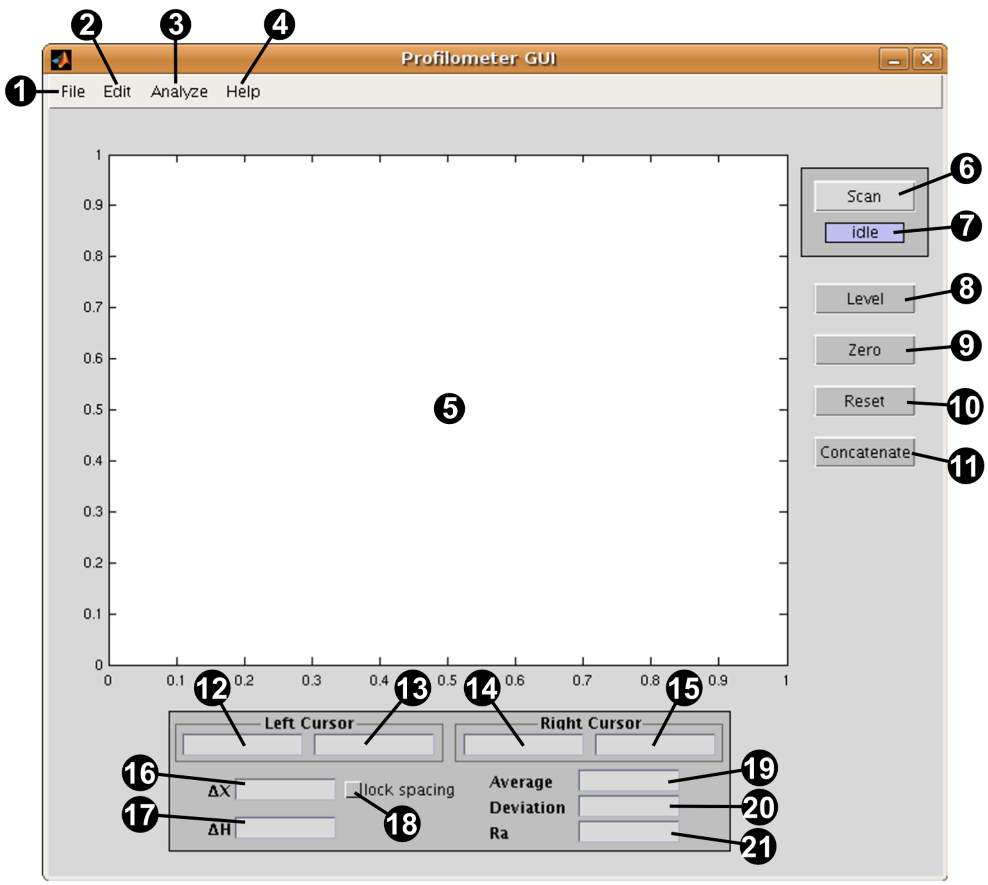


Figure 1: Opening screen when *profilometerGUI.m* successfully loads.

3 Reading-in profilometer data

Once a profile has been scanned by the profilometer, that data can then be retrieved by the computer. While data can be sent from the profilometer, unfortunately the profilometer cannot read incoming data. This means that the serial port of the computer cannot instruct the profilometer to begin sending data. There are three ways you can instruct the program to watch for incoming profilometer data: 1. select *Scan Data* from the *File* drop-down menu (number 1 in Figure 1), 2. press **Ctrl + I**, or 3. click on the *Scan* button on the right side of the panel (number 6 in Figure 1).

Once the scan function has been called, the scan status field (number 7 in Figure 1 will change from *idle* (Figure 2(a)) to *waiting* (Figure 2(b)). The status will remain at *waiting* until either data is sent from the profilometer or the user clicks on the *Scan* button to return the scan status to *idle*. When the program detects data being sent by the profilometer, the status field will change from *waiting* to *active* (Figure 2(c)). At this point the *Scan* button will become inactive until all data is successfully read in.

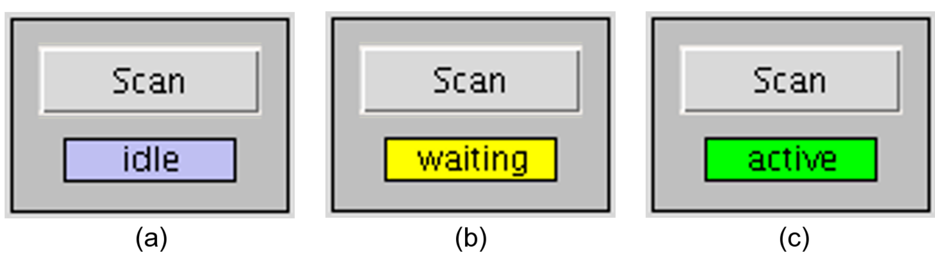


Figure 2: Values that the scan field can assume. (a) When status is set to *idle*, the program is not checking for data from the profilometer. (b) When the status is set to *waiting*, the program is actively watching for data to be sent to the serial port from the profilometer. (c) When the status reads *active*, data is currently being transferred.

To read in data from the profilometer, first the scan status must be set to *waiting*. At this point, you must press the button labeled *plot* on the profilometer. If this was successful, you will see a countdown of values on the profilometer screen on the left side. Once all of the data is read in, the scan field will automatically return to *idle* and the data will be plotted to the screen. This is shown in Figure 3.

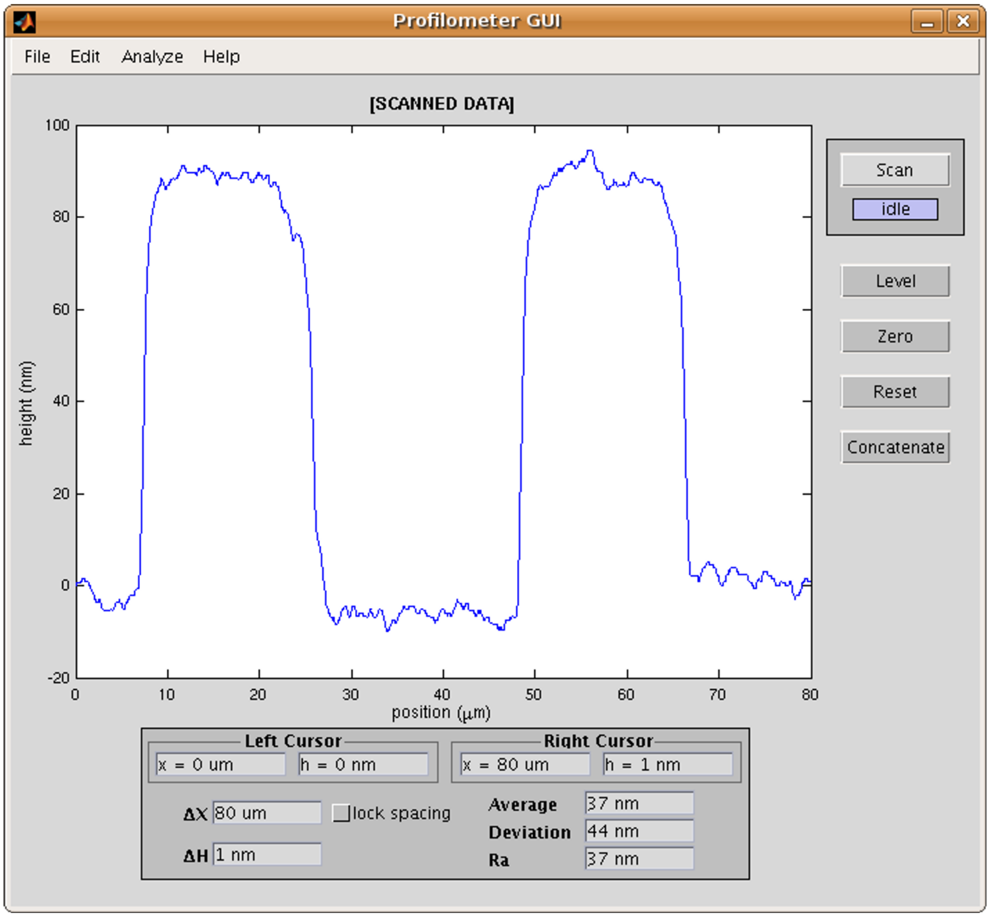


Figure 3: Once data is retrieved from the profilometer through the serial port, the resulting scan is plotted in the program window. The title *[SCANNED DATA]* indicates that the current plot was scanned directly from the profilometer and has not been saved.

4 Loading existing profilometer data

Once scanned data has been saved, it can be accessed by loading the appropriate text file. Text files containing profilometer data can be loaded by either selected *Open File* from the *File* drop-down menu (number 1 in Figure 1) or by pressing **Ctrl + O**. When *Open File* is selected, the menu in Figure 4 will appear. Files can be selected by either clicking once on the file name and then clicking on the *load* button, or by double-clicking the desired file name. It is possible to navigate through directories by double-clicking on a selected folder or by double-clicking on .. to move up one directory.

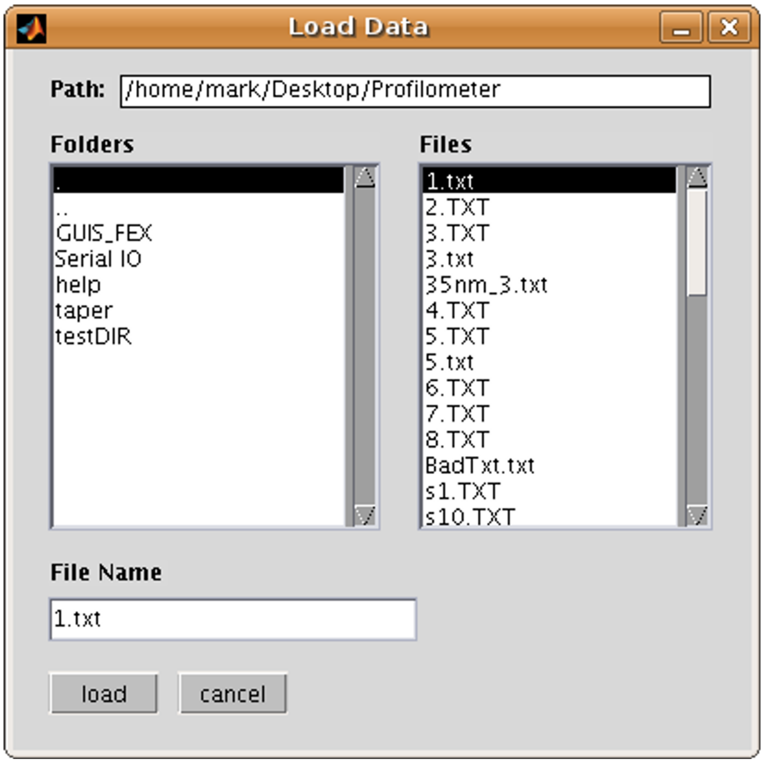


Figure 4: Selecting *Open File* will cause this menu to appear. Folders are listed on the left-hand side, while text files are listed on the right-hand side.

Once a file name has been activated, it will be plotted to the program window, as shown in Figure 5.

5 Saving profilometer data

Once a profile is plotted on the program window, it can either be saved as data in a text file or it can be saved as an image.

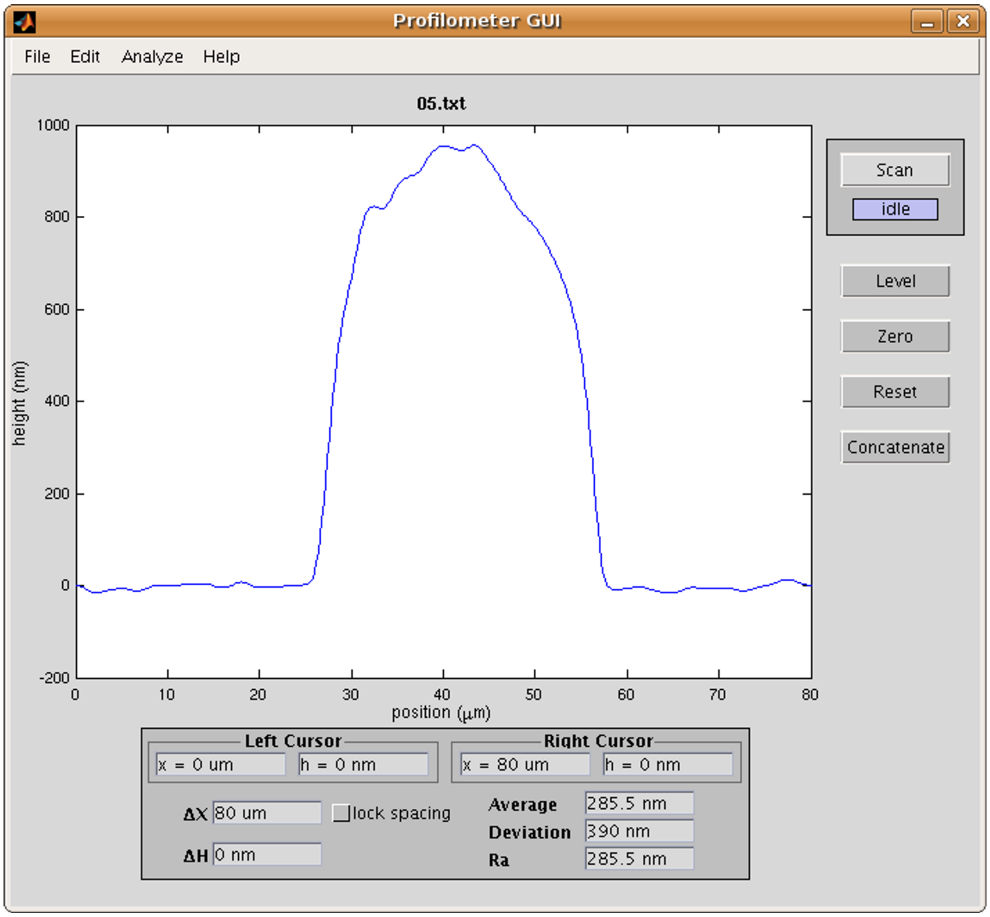


Figure 5: A loaded file plotted in the program window. The title in this example, *05.txt*, indicates that this is data that has been saved after being read in from the profilometer or that it was loaded from an existing text file.

5.1 Saving data

To save a profile in the form of textual data, select *Save* and then *Data* from the *File* drop-down menu. The shortcut key combination is **Ctrl + S**. If there is no plot in the program window, nothing will happen. However, if a plot exists, then the menu in Figure 6 will appear.

A file can be saved in a couple of ways. An existing file can be overwritten by by first clicking on the existing file name and then clicking on *save*, or a file can be overwritten by double-clicking on the desired file name. Otherwise,

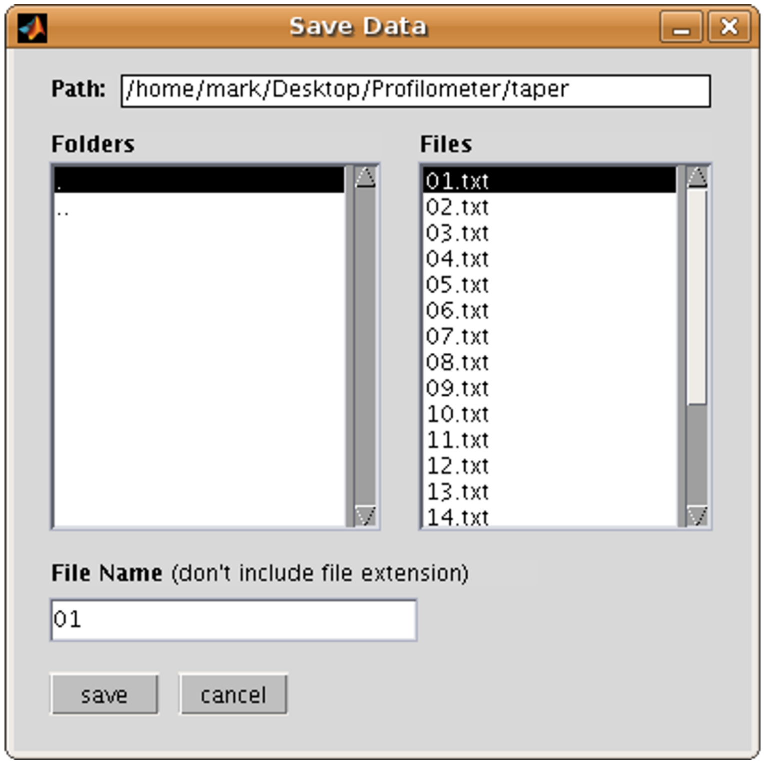


Figure 6: Selecting *Save* and *Data* will cause this menu to appear. Folders are listed on the left-hand side, while text files are listed on the right-hand side. When entering a file name, don't include the extension.

a file name can be manually entered in the *File Name* field. Once this is completed, a new text file will be created in the current directory with a .txt extension appended to it. This file can later be loaded for further analysis.

5.2 Saving an image

To save a profile as an image, select *Save* and then *Plot* from the *File* drop-down menu. The shortcut key combination is **Ctrl + P**. This will cause the menu in Figure 7 to appear.

This menu allows you to see approximately what your image will look like when it is created. As aspects such as font size, font type, units, and image size are altered, they will be reflected in the small plot preview in the upper-left quadrant of the window. This menu allows you to save your image

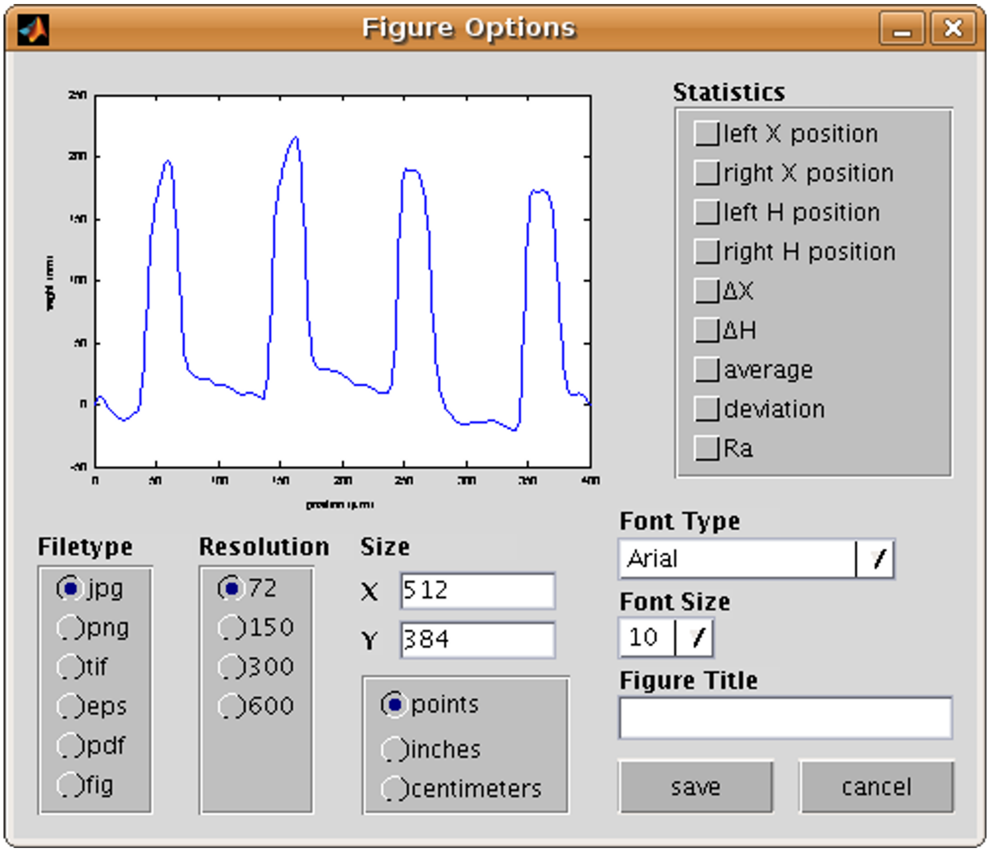


Figure 7: Selecting *Save* and *Plot* will cause this menu to appear. Selectable image characteristics include selecting the file type, resolution, image size, image units, font type, font size, image title, and including statistical text applicable to the plot.

as a raster (JPG, PNG, TIF), vector (EPS, PDF), or Matlab (FIG) image. It will also allow you to specify the resolution (72, 150, 300, or 600), which is specified in terms of points per inch. The size of the image can be set using either points, inches, or centimeters. Only two font types are available, Times New Roman or Arial, which allows you to specify a serif or a sans serif font. The font size can range between 6 and 64. The figure title can be any string you can contrive.

The statistics area of the menu allows you to check any of the listed options you would like to appear in the saved image. Any of the checked options will appear along the right side of the image, and the values are determined by the position of the left and right bars.

An example of a saved image using this menu is shown in Figure 8.

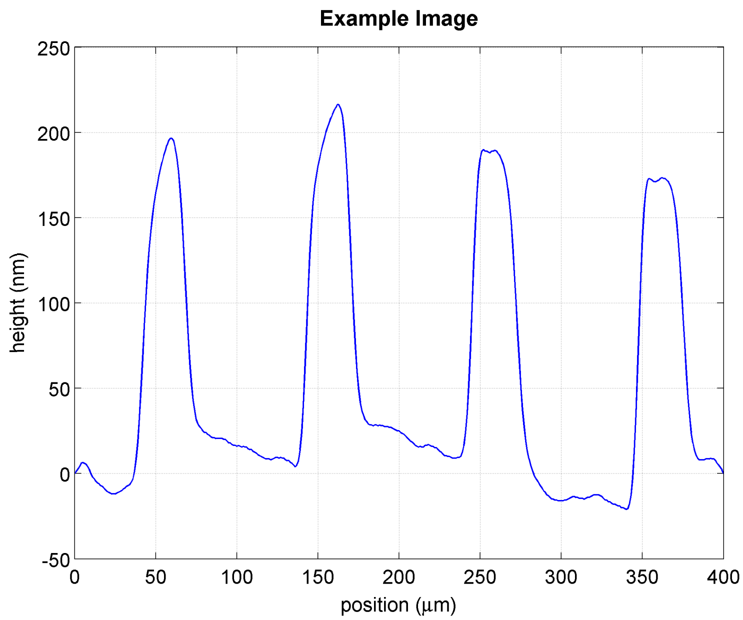


Figure 8: An image that was created using the *Save Plot* option. This image was created to be 11 cm wide with a resolution of 300 points per inch, a font size of 10 points using an Arial font, and was generated as a PNG image.

6 Analyzing data

Once a profile has been plotted to the program window, you can query points on the plot to produce useful information regarding your sample. To understand what information is available, refer to numbers 12 through 21 on Figure 1.

Numbers 12 through 15 will display position and height data for the left and right cursors. These cursors can be set by using the left mouse button and right mouse button to produce left and right cursors, respectively. Left click on any spot on the plot and the left cursor will be moved to that location. Similarly, the right cursor will move to wherever a right click is made with the mouse on the plot. As these cursors are set, information regarding the position of these cursors as well as the height of the data at those points will appear in numbers 12 through 15. The position fields, numbers 12 and 14, can also be manually entered by clicking on the field and typing in a number.

Fields 16 and 17 correspond to the change in position between the two cursors (ΔX) and the change in height between the points at those locations (ΔH). ΔH is perhaps the most commonly used measurement when dealing with profilometry, since most user tend to want to know the step change from one structure or film to another. An example of this is shown in Figure 9. The value for ΔX can also be entered manually.

Next to the difference fields can be found the *lock spacing* check box, which corresponds to number 18 in Figure 1. When this box is checked the spacing between the left and right cursor is locked. You can at this point left or right click on the figure to simultaneously move both cursors. If you click so that one of the cursors would move off of the data range, it will stay at the data's furthest point. Then once you click anywhere back on the image so that both cursors can fit in the range, the spacing between cursors will be maintained at the original value at which they were locked. The lock spacing can be overruled, however, if data is manually entered in either of the cursor position fields or the ΔX field.

Fields 19 through 21 include statistical data such as the average height, height deviation, and surface roughness, respectively. The average is computed as the mean height between the two cursors, and the deviation is computed as the standard deviation between those points as well. The surface roughness is a measure of the roughness of the profile between the two cursors. Figure 10 demonstrates the usefulness of statistical data.

7 Manipulating data

Once a profile has been plotted to the program window, it can be manipulated using the *Analyze* drop-down menu or the buttons to the right of the plot window (numbers 8 through 10 in Figure 1). These functions include leveling the profiling data, creating a zero point for the data, and reseting the displayed data.

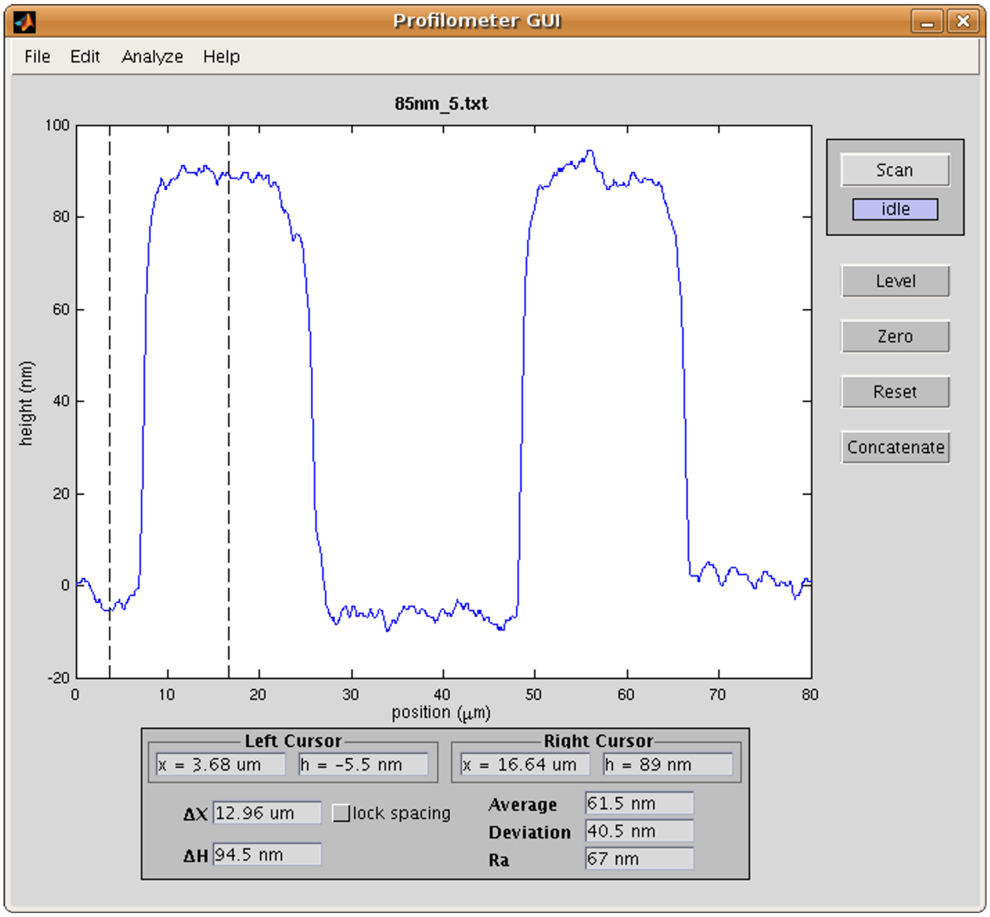


Figure 9: The usefulness of using the left and right cursors to measure the step change from one feature to another. The left and right bars are shown placed on the feature on the left of the plot. The displayed height different, ΔH, is 94.5 nm.

7.1 Leveling

Leveling is accomplished by shifting the data to result in the points at the left and right cursors to be at the same value. First, you must place your left and right cursors along the points that you would like to level to. There are three ways of calling the leveling function: 1. select *Level* from the *Edit* drop-down menu (number 2 in Figure 1), 2. press **Ctrl + L**, or 3. click on the *Level* button on the right side of the panel (number 8 in Figure 1). Figure 11 demonstrates the effect of leveling data.

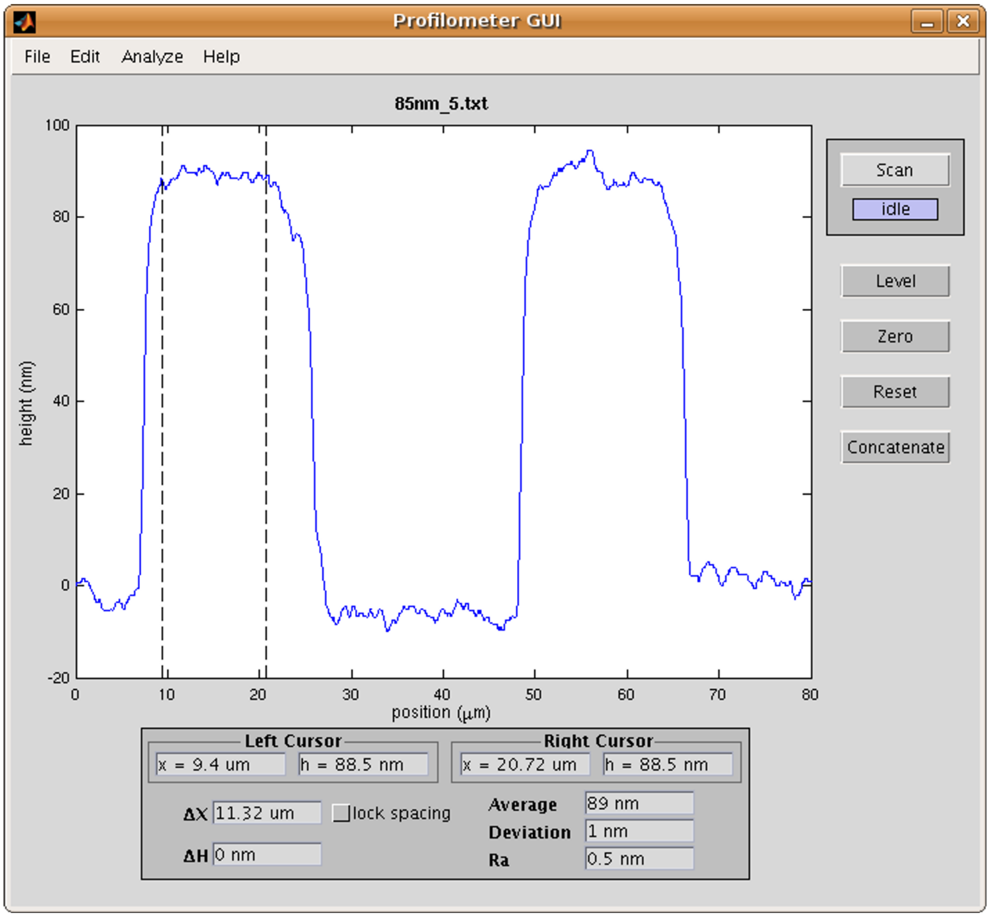
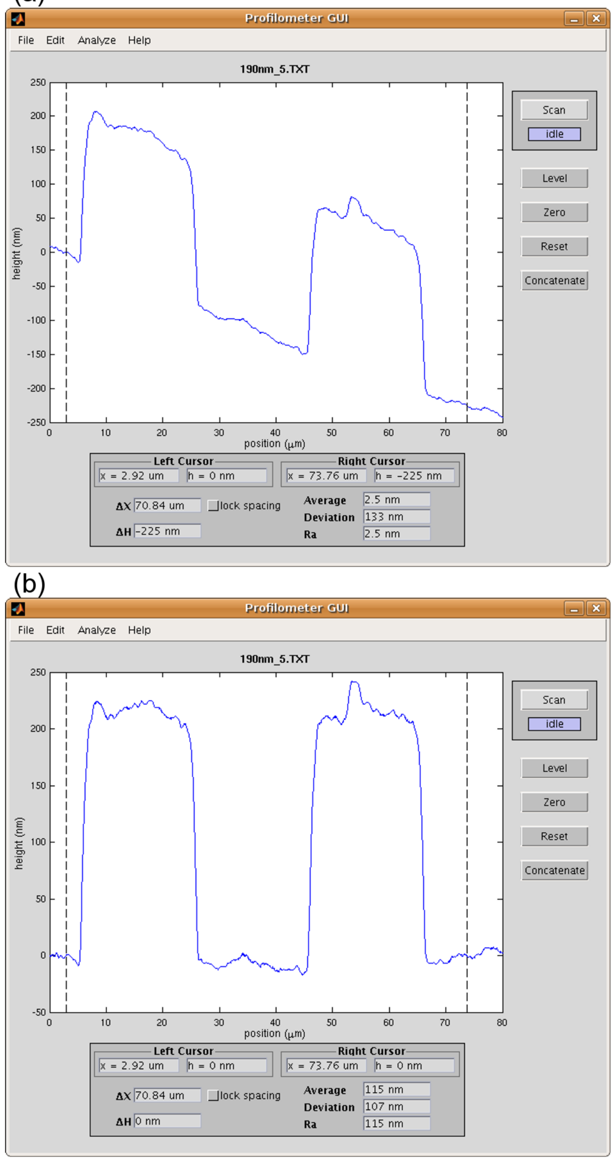


Figure 10: The left and right cursors are used over a somewhat flat segment of this feature to highlight the height average, deviation, and the surface roughness. In this case, the average is displayed as 89 nm with a deviation of 1 nm, and the surface roughness is shown as 0.5 nm.

7.2 Zeroing

Zeroing is choosing a point on the plotted data to correspond to zero, and the remaining data is shifted accordingly. This is useful when absolute values need to be measured, for example, the average height of a particular feature. This allows you to select a point to have a height of zero. The zero point is determined by the position of the left cursor. There are three ways of calling the zeroing function: 1. select *Zero* from the *Edit* drop-down menu (number

(a)



(b)

Figure 11: Leveling data. (a) The data starts out slanted, so the left and right cursors are placed to determine the leveling points. (b) Once the *Level* button is clicked, the data shifts according to the left and right cursors and results in better leveled data.

2 in Figure 1), 2. press **Ctrl + Z**, or 3. click on the *Reset* button on the right side of the panel (number 10 in Figure 1).

7.3 Reseting

Reseting is reloading the original data after performing functions such as level or zero. This will discard any changes made to the data and re-plot the original, while leaving the left and right cursors in their most recent position. There are three ways of calling the reset function: 1. select *Reset* from the *Edit* drop-down menu (number 2 in Figure 1), 2. press **Ctrl + R**, or 3. click on the *Zero* button on the right side of the panel (number 9 in Figure 1).

8 Concatenating data

Data concatenation is a more advanced feature of this program, and will most likely find application in only a few specific cases. The call to the concatenate function can be done in one of three ways: 1. select *Concatenate* from the *Analyze* drop-down menu (number 3 in Figure 1), 2. press **Ctrl + A**, or 3. click on the *Concatenate* button on the right side of the panel (number 11 in Figure 1). Once a profile is plotted in the program window and the concatenate function is called, the menu in Figure 12 appears. The data that is captured includes the following: the data set number (set), the left cursor height measurement (Hl), the right cursor height measurement (Hr), the height difference between the cursors (Hdiff), the average height between the cursors (Havg), the deviation of the height between the cursors (Hdev), and the surface roughness between the cursors (Ra). Also on this menu is a field to enter a number for *spacing between data sets (um):*. This number corresponds to the distance between the features that are being added to the concatenate menu.

After the function has been called the first time, every other time it is called the current data will be added to the existing data. The purpose of the concatenate function is to allow you to string several consecutive profile scans together into one cohesive image. For example, if you would like to profile features over a length greater than the scope of the profilometer, you can take multiple scans and then put them together using this function. When multiple points are added to the set, it looks something like Figure 13. Once all of the desired data is gathered, it can then be saved by clicking on the

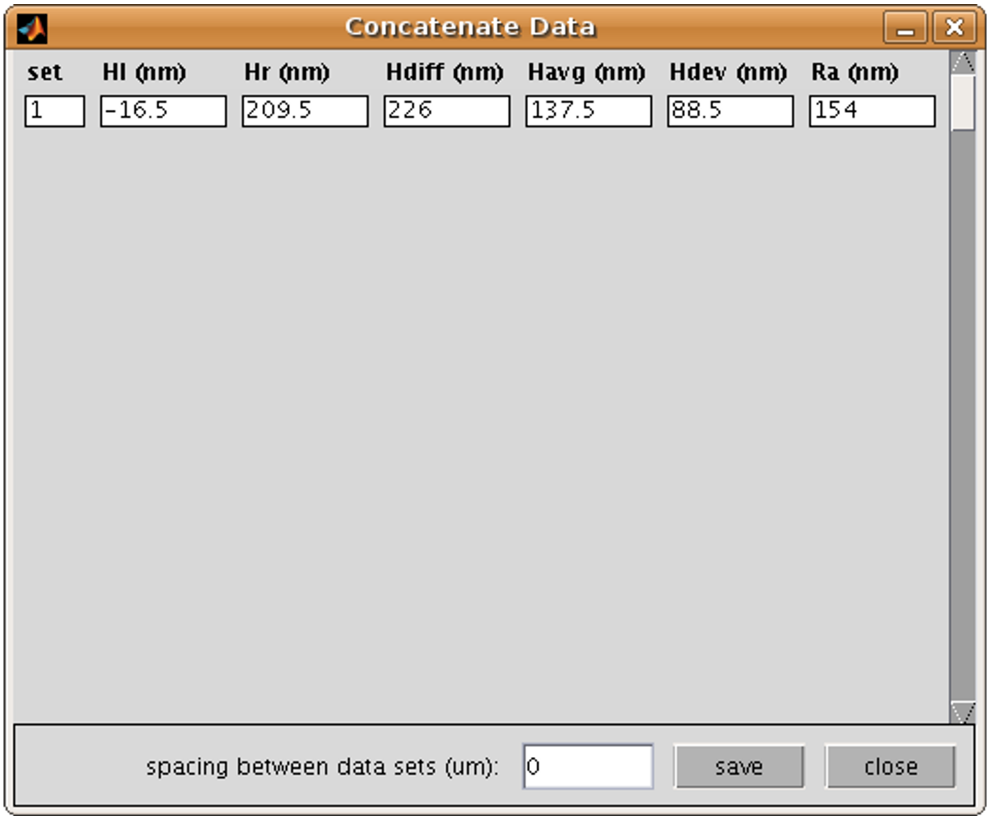
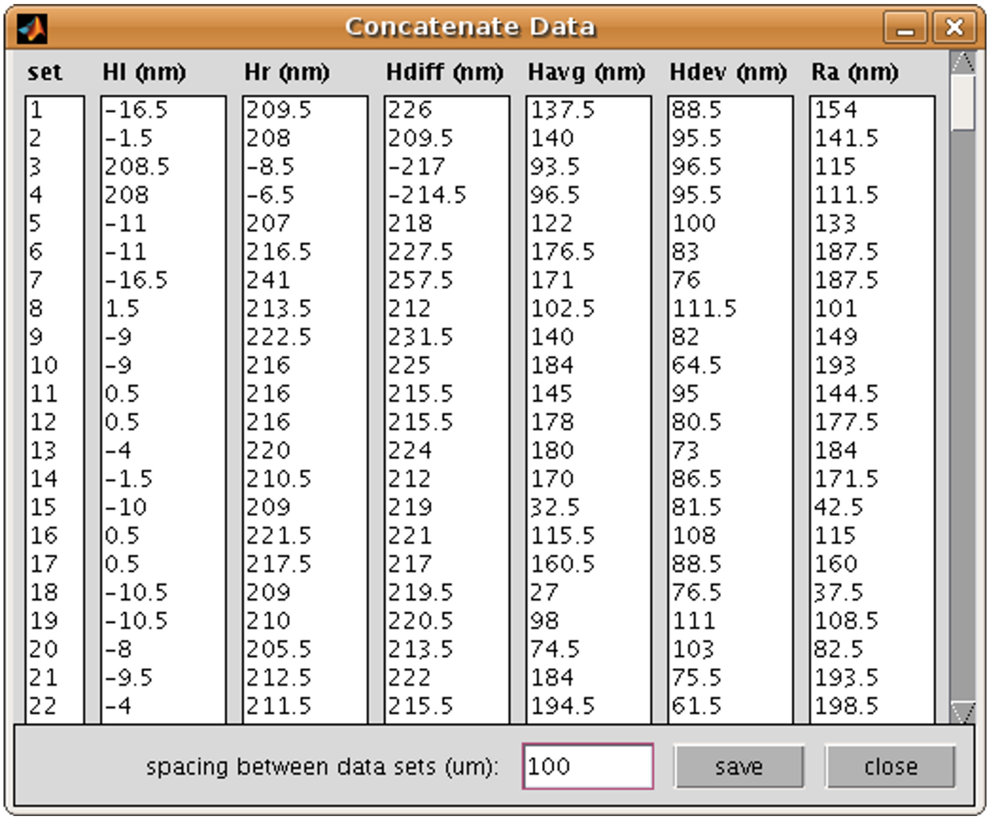


Figure 12: The concatenate data menu the first time it is called. It loads the following values determined by the position of the left and right cursors: the data set number (set), the left cursor height measurement (Hl), the right cursor height measurement (Hr), the height difference between the cursors (Hdiff), the average height between the cursors (Havg), the deviation of the height between the cursors (Hdev), and the surface roughness between the cursors (Ra).

save button on the concatenation menu.

In order to view the results of the concatenated data, it is then necessary to load it using the *Open File* function which can be found under the *File* heading of the drop-down menu. Concatenated data files are text files, just like profilometer data files, but the program can distinguish between which type is being loaded. When a concatenated data file is being loaded, the menu shown in Figure 14 appears and inquires which features you would like to plot. The possible features include: the left cursor height (Hl), the right



set	Hl (nm)	Hr (nm)	Hdiff (nm)	Havg (nm)	Hdev (nm)	Ra (nm)
1	-16.5	209.5	226	137.5	88.5	154
2	-1.5	208	209.5	140	95.5	141.5
3	208.5	-8.5	-217	93.5	96.5	115
4	208	-6.5	-214.5	96.5	95.5	111.5
5	-11	207	218	122	100	133
6	-11	216.5	227.5	176.5	83	187.5
7	-16.5	241	257.5	171	76	187.5
8	1.5	213.5	212	102.5	111.5	101
9	-9	222.5	231.5	140	82	149
10	-9	216	225	184	64.5	193
11	0.5	216	215.5	145	95	144.5
12	0.5	216	215.5	178	80.5	177.5
13	-4	220	224	180	73	184
14	-1.5	210.5	212	170	86.5	171.5
15	-10	209	219	32.5	81.5	42.5
16	0.5	221.5	221	115.5	108	115
17	0.5	217.5	217	160.5	88.5	160
18	-10.5	209	219.5	27	76.5	37.5
19	-10.5	210	220.5	98	111	108.5
20	-8	205.5	213.5	74.5	103	82.5
21	-9.5	212.5	222	184	75.5	193.5
22	-4	211.5	215.5	194.5	61.5	198.5

Figure 13: Once several data points have been added to the concatenated menu, it will look more like this.

cursor height (Hr), the difference in height between the cursors (Hdiff), all of the data points between the cursors (H), or any combination of the average height (Havg), the deviation (Hdev), and the surface roughness (Ra). One the desired options are selected, you simply need to click on *plot data* to create a plot in the program window.

Figure 15 shows an example of a concatenated data set plotted using the average height, deviation (shown as blue error bars), and surface roughness (shown as red error bars). The resulting plot can then be saved as an image using the *Save Plot* function under *File* in the drop-down menu.

Figure 14: When loading a concatenated data set, this menu allows you to select what to plot. You can plot either the left cursor height (Hl), the right cursor height (Hr), the difference in height between the cursors (Hdiff), all of the data points between the cursors (H), or any combination of the average height (Havg), the deviation (Hdev), and the surface roughness (Ra).

9 Conclusion

I hope that this program proves to be useful in your research. This is still a work in progress, so don't be surprised if you find any strange behavior or errors from time to time. Feel free to alter the code for your own purposes, or contact me with any problems that you may discovered at marknhamblin@gmail.com.

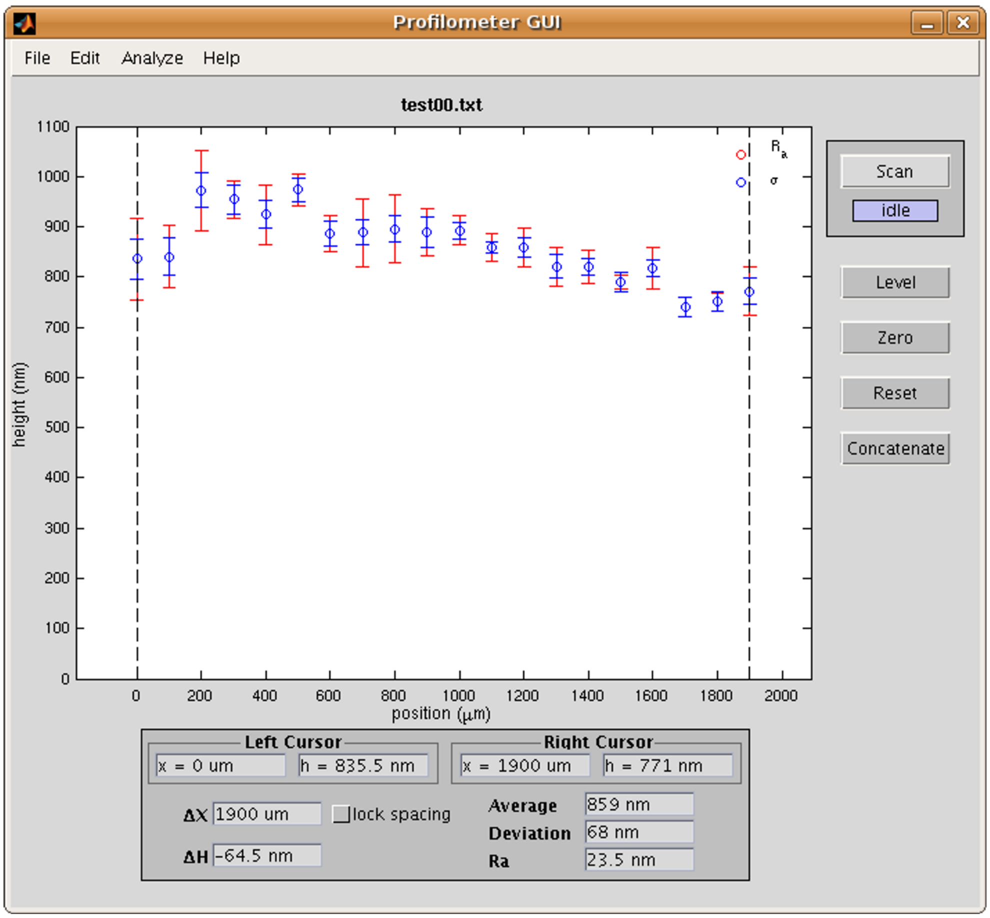


Figure 15: Concatenated data plotted in the program window. The data shown here represents the average height for several features with blue error bars indicating deviation and red error bars indicating surface roughness.