

# Height Map Viewer

## Tool not only for the Laser Engraved Sample Exploration

Jana Hájková

Department of Computer Science and Engineering  
University of West Bohemia  
Pilsen, Czech Republic  
e-mail: hajkovaj@kiv.zcu.cz

**Abstract**— The paper describes a complex software tool designed for exploring height maps. The tool facilitates tasks like viewing the height maps in 2D and 3D perspectives, measuring their dimensions, computing various statistics for them and, most importantly, mutually comparing several of them for similarity. The tool originates from a research in the area of modeling and simulation of the laser engraving process and is used for exploring surface laser engravings digitized by a confocal microscope. It may, however, be used with any general height maps described in the input format, which is designed to be easy to create and human readable. The main aim of this paper is to introduce the useful tool to the experts.

**Keywords**-height map; visualization; exploration; statistics; comparison.

### I. INTRODUCTION

The effort to develop a height map viewer was part of a larger project dealing with modeling and simulation of the laser engraving process. Because the results of physical laser engraving are very sensitive to various physical parameters of the used material as well as the settings of the laser device, a simulation model has been developed at the New Technology Centre at the University of West Bohemia in Pilsen for predicting the engraving results in order to save both time and material costs. The predictions are made based on data obtained from physical samples engraved so far and various statistics computed from them. The physical samples vary both in used material and laser settings. They are scanned using a confocal microscope and saved in the form of a height map. However, this is not sufficient. In order to use these height maps with the simulation model, they must be explored in more detail to discover various dependencies, similarities or differences, and to reject those samples that are significantly affected by any adverse effects not related with the laser engraving process, such as damages in the used material. Because the huge amount of data and the high costs of human resources, a high level of automation is desirable, especially in comparing several samples for similarity.

As no suitable tool was found among the existing ones, it was decided to develop a new one that fits required purposes the best. The description of this tool is the main aim of this paper. Even though some its functions are closely associated with laser-engraved samples (especially the pit/area detection

algorithms), most its functions are general enough to use it for detailed explorations and comparisons of any height maps represented in the corresponding input format, which is described in Section III.A. The functions of the height map viewer are described in Section IV in more detail.

Laser engraving is a technique frequently used in various branches of industry and science. During the laser engraving process, the surface of a material is exposed to the activity of a laser beam, which affects and modifies it. As the electromagnetic radiation of the laser beam strikes the surface, the material starts to heat and, if the laser intensity is high enough, the rising temperature evokes material ablation. More detailed description of the ablation process can be found in [1][2].

During our research, two different types of engravings were processed: single-point engravings and motion engravings. Examples of both can be seen in Figure 1. For each physical sample, a scenario containing a set of key parameters was prepared (number of laser pulses, laser beam intensity, motion speed, and the like). Then, a corresponding physical sample was engraved (BLS-100 Nd:YAG solid-material, lamp-pumped laser with the wavelength of 1064nm was used) and scanned using a confocal microscope (for described samples Olympus LEXT OLS3100 [11] was used).

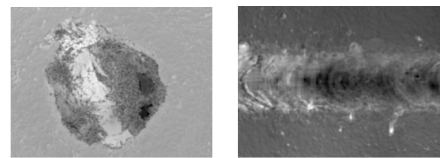


Figure 1. Single-point and motion engravings (used material: cermet).

A 3D view on a sample exported from the confocal microscope can be seen in Figure 2 (the original figure was white on black, so this is a negative). The confocal microscope also provides other data formats on export, such as 2D top views (both in color and in gray scale) and, more importantly, heights description in the form of CSV file. The scanning of the sample surface is provided in a discrete way. Each sample is measured in many parallel cross-sections with a pre-defined step distance. The height coordinates (one for each cross-section) are saved in plain text CSV file. Input and output file formats are the main content of Section III.

The application and its main functions are described in Section II and Section IV. Section V concludes the paper.

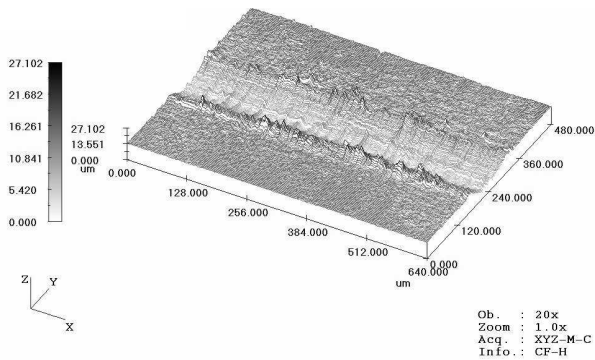


Figure 2. Sample 3D view exported from the confocal microscope (negative image).

II. PROGRAM DESCRIPTION

The Height Map Viewer is a desktop application licensed under CC-BY-NC-S. Downloads are available under [9].

The application works in two modes that can be switched between: map exploration mode and map comparison mode. The map exploring mode can be used to visualize maps in 2D and 3D perspectives. Moreover, it offers tools for performing measurements, exploring cross-sections, as well as some functions specific for laser-engraved samples, such as automatic detection of heat-affected area [7]. It also allows exporting the sample or its parts in several formats. The map comparison mode contains tools that can be used to mutually compare two samples for similarity. The samples can be overlapped and the difference visualized. Also, various statistics related to the difference can be computed.

III. INPUTS AND OUTPUTS

The input and output formats of data are mostly text-based in order to allow preparing and pre-processing the input data and post-processing the output data using the many powerful text utilities and to allow preparing a batch script for it.

A. Height Map Input Format

The application uses an input format that some confocal microscope can produce directly and, if not the case, that the output of most confocal microscopes can be easily converted into. This is important in order to save time on data pre-processing when measuring physical samples. The format is relatively simple - it consists of several headlines containing metadata followed by an array of floating point values representing the height coordinates.

Table I summarizes the list of possible headlines that can be included in the input file. The headlines can be used in any order. However, it is important that the DataLine describing the array of height coordinates is used before the coordinates themselves appear. The first column of the table shows the format of each individual line, the second one explains its meaning and shows other acceptable values if there are some. The color of rows in Table I specifies, whether or not the line has to be included in the file, (mandatory lines are highlighted with gray color). Besides

settings described in Table I, the headlines of the file can also contain other information such as calibration data, various file names or comments. Such lines are ignored during the file load process.

TABLE I. HEADLINES THAT CAN BE USED IN THE INPUT FILE.

Line Format	Explanation
Data type = Height	indicates a height map
Xcv = 0.625 Ycv = 0.625	step size in the X and Y direction (sampling raster size); this value is used for computing the real size of the sample. If no value is defined, step = 1 is used
Xunit = um Yunit = um Zunit = um	real units for all three axes (um = μm)
Along x-axis	indicates the direction of sample measuring (x-axis: each data line represents one column of the sample; y-axis: sample is represented row by row)
DataLine, Pos = 0, Pos = 1, ... , Pos = 300	line placed before the height coordinates data, the number of values indicates the number of rows (x-axis) or columns (y-axis) measured in the sample
0.0,2.6499, 2.6556,2.6631...	floating point values representing the height coordinates of the sample surface in the particular measuring points; separated with comma, the first value of the row represents the real distance of the row (column) from the borderline of the sample

To gain a better imagination of how the data look like, the following example shows a description of a small (five rows by ten columns) sample. The measurement was performed along to the x-axis; it means that lines of the height map file represent columns of the sample (Figure 3a). Then the direction of saved values (headline Along) from x-axis to y-axis was changed. In such case, the file would represent a sample with ten rows and five columns. In both figures, each value is depicted as the square of the gray scale adequate to the height value (Figure 3b).

```
Data type = Height
Xcv = 0.5
Ycv = 0.5
Xunit = um
Yunit = um
Zunit = um
Along x-axis
DataLine, Pos = 1, Pos = 2, Pos = 3, Pos = 4, Pos = 5
0.00,0.0,0.0,0.59,1.26,1.62
0.50,0.0,0.92,2.0,2.82,3.27
1.00,0.59,2.0,3.27,4.31,4.92
1.50,1.26,2.82,4.31,5.63,6.53
2.00,1.62,3.27,4.92,6.53,7.99
2.50,1.62,3.27,4.92,6.53,7.99
3.00,1.26,2.82,4.31,5.63,6.53
3.50,0.59,2.0,3.27,4.31,4.92
4.00,0.0,0.92,2.0,2.82,3.27
4.50,0.0,0.0,0.59,1.26,1.62
```

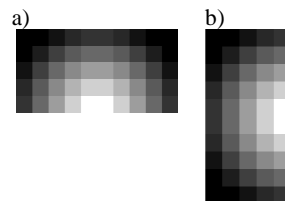


Figure 3. Visualization of the sample, where the value for Along as: (a) x-axis; (b) y-axis was used.

## B. Outputs and Exports

During the exploration of a height map, some results typically need to be saved for future use. Thus, the application allows saving parts of the height map, their visualizations or cross-section plots. The possible outputs and their formats are described in the following sections.

### 1) Sample Surface

The whole sample can be saved in two different ways. The first one saves the whole sample or its part bordered by a selection rectangle in the text format described in Section A. It can be used, e.g., to cut off border areas of the height map which should not be processed or to crop the height map after rotating it. If the whole height map is selected, no height map values are lost in comparison with the original surface. The saved file can be reloaded and processed in the same way as the original one.

The second way saves a grayscale representation of the current view on the height map. The user can choose from several image formats – BMP, JPG, and PNG. The current view is always saved with all the tools (selection, cross-section lines, ruler, etc.) that are actually shown. This is useful when measures or statistical data are desirable to view along with the height map itself (as shown in Figure 4), which is typical for images intended to be published.

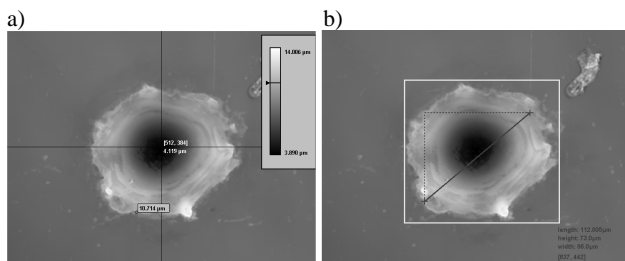


Figure 4. Images saved with (a) cross-sections and height scale; (b) ruler and selection rectangle.

### 2) Cross-Sections

When working with height maps, it is sometimes useful to save separate cross-sections for further processing. Because the 2D visualization uses them as its fundamental part, the possibility of exporting them is a native part of the height map exploration. The cross-sections can be saved both as images and as sets of values. The set of values is exported as a simple CSV file. This allows further processing of the data, for example in a spreadsheet processor. The file contains the described direction (x – vertical cross-section; y – horizontal cross-section; line – cross-section along the line segment) followed by the actual height coordinates, each on its own line. The export as an image enables its further comparison, presentation or retainment. Several parameters of the image export (background color, plot height scale, font size, and the like) can be set. An example of a simple cross-section plot can be seen in Figure 5. It is possible to export vertical or horizontal cross-sections from the whole sample or just from the area bordered by the selection rectangle. It is also possible to draw an arbitrary line and to get the surface cross-section along that line. For the line rasterization, the DDA algorithm [13] is used.

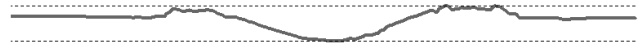


Figure 5. Exported simple cross-section plot.

## IV. IMPORTANT FUNCTIONS

The important and useful functions of the viewer are described in the following sections. Besides the principal function of visualizing the data and couple of specialized functions for exploring them, there are also general functions not described in detail. Especially functions for opening and saving the data (the format alternatives were mentioned in Section III.B), selecting them, rotating them, and the like belong into this group.

### A. Height Map Visualization

During the height map visualization, it is necessary to map the three-dimensional object (surface of the sample) onto a two-dimensional plane (screen or paper). There are two possible approaches that can be successfully combined, namely the three orthogonal 2D views on the object along with its 3D visualization. This combination is also often used by many 3D modeling programs.

#### 1) 2D Visualization and Control

The first approach of the 3D object visualization is the usage of three orthogonal views on a 2D plane. As shown in Figure 6, there is one top view together with two cross-section plots.

The top view is represented by a grayscale image, where each point of the surface is represented in gray shade corresponding to its height coordinate. There are also two orthogonal lines in the top view. They indicate the position of the cross section plots shown left and below the top view. By moving these lines, it is possible to explore the exact shape of the surface. To explore the height map in a more precise way, a ruler and a heightscales can also be used. Their usage is described in Section B.

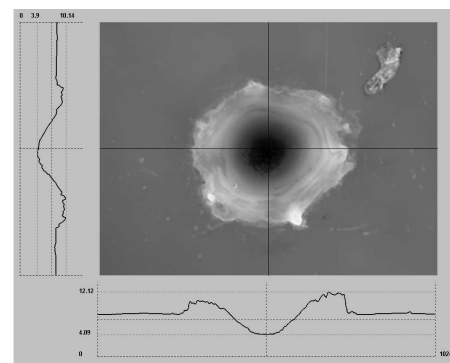


Figure 6. The three views of the 2D visualization.

For the control of 2D visualization it is possible to use only the mouse clicking and dragging and also a specialized control panel that is placed on the right side of the main window. In the main (top) view on the sample selection rectangle can be shown or hidden (only by one single click in the view), its size and position can be changed (if the user

drags the border by mouse). If cross-section lines are shown, they can be moved (also by drag and drop) and the cross-section relief of the moved direction is modified immediately. Selection and cross-section lines positions can be adjusted also in vertical and horizontal views.

To enable better and exact height map exploration, ruler and heightscale can be used. Both tools are activated on the viewer initiation; they can be activated and deactivated as needed (in menu or by shortcuts). Their usage is described in Section B.

The control panel (shown in Figure 7) in the right part of the window is divided into three parts. The first one (Sample) informs about the height map size (according to values Xcv and Ycv defined in the input file – see Table I) and the minimal and maximal heights on the surface. The second part (Selection) enables exact setting of selection rectangle (its each border), its motion or changing of its height and width. For each operation a special button can be used. It is also possible to set the exact proportion of height and width of the selection area. If it is activated, the selection proportions are fixed during each manipulation. In this part of control panel also the real size of selected area is computed. Value named as Limit is a threshold computed automatically from the sample that is used during the automatic detection of the heat-affected area described in Section IV.C. The last part of the control panel (Cross-section) works with cross-section lines, enables their exact motion (also according to their real position) and enables to show and hide them. Control panel contains also several individual buttons for the selected area saving, 3D visualization initializing and closing the whole viewer.

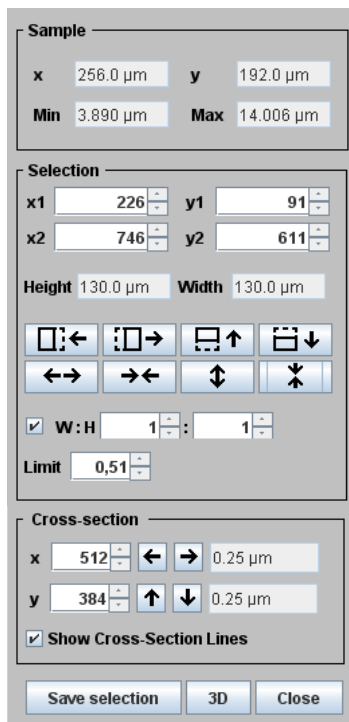


Figure 7. The control panel on the right side of the viewer window.

2) 3D Visualization and Control

If viewing the height map as a whole is desired, 3D visualization can be used (see Figure 8). The 3D plot is very realistic, but exploring the height map in detail or performing precise measurements is difficult using this view, because the control of the object space orientation is more complicated. There are two modes of visualization that can be switched between - a smooth surface (see Figure 8) and a wire model (see Figure 9). In both modes, the surface plot can be moved, scaled, and rotated. Both modes use the height map visualization module [8].

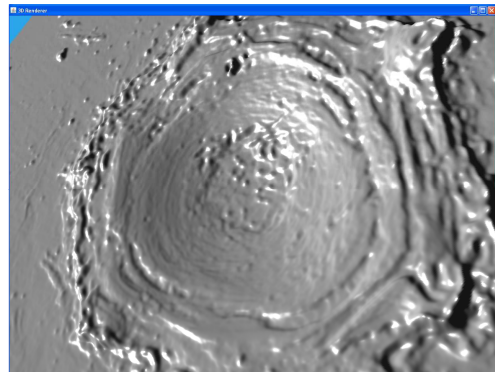


Figure 8. 3D height map visualization of a smooth surface.

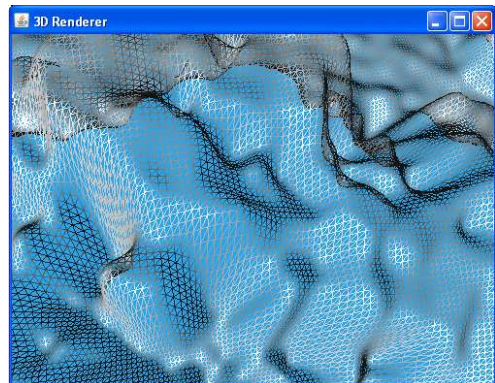


Figure 9. Wire model of the 3D surface with a help shown in the top left corner.

B. Admeasurements and Volume Computations

The height map viewer provides detailed surface exploration using several measurement tools. The first one is called ruler. If activated, the coordinates of the current cursor position are shown in the right bottom corner of the central view. To measure a distance, two points on the surface have to be selected. This can be done by the clicking on the surface using the right mouse button. The selected points are visualized on the surface as small crosslines. When the second point is selected, their distance is computed and the result is shown in the right bottom corner of the central view. A similar function can be used in both cross-section views. In this case, the distance of heights of the two points can be measured as well. An example of using the ruler can be seen in Figure 10 (the top image shows the central view and the

bottom image the horizontal cross-section view). The selected points can be discarded by another click using the right mouse button. The ruler control points in each particular view are independent of each other.

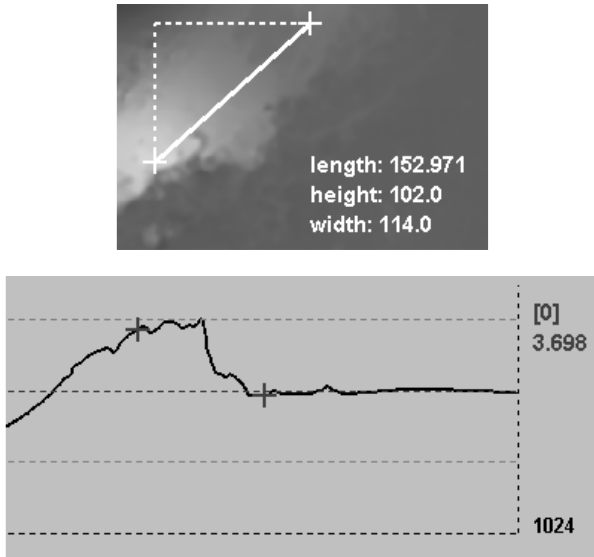


Figure 10. Ruler function - an example of results.

The second tool is the heightscales. If activated, the grayscale from white (maximum) to black (minimum) is shown in the right top corner (see Figure 11). The height of the current cursor position is marked on the height scale. When the cursor moves outside the central view, the height of the intersection of the cross-section lines is marked instead. The heightscales tool shows also the height of the current cursor position (as shown in Figure 12) and description of the position of cross-section lines crossing. It is activated in all the three views simultaneously using the heightscales tool.

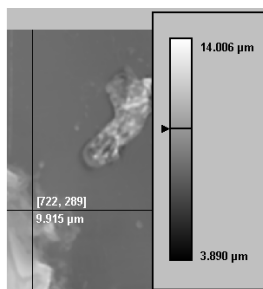


Figure 11. Heightscale function – an example of results.

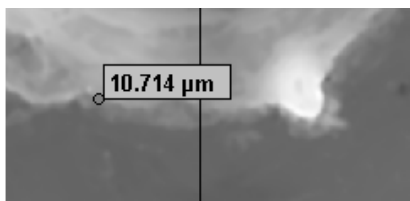


Figure 12. Height of the current position.

The third tool that can help in exploring the sample is statistics calculator. It summarizes the information about the sample (e.g., its size or minimum and maximum values) and computes the volume of retained/ablated material. The volume above and below the basic material level is computed either for the whole surface or for the surface of the currently selected area. It is also possible to provide an automatic detection of the heat-affected area directly from the statistics dialog. Because the computed volumes depend on the material basic level setting, the user can choose from three different modes of computing it (also shown in Figure 13).

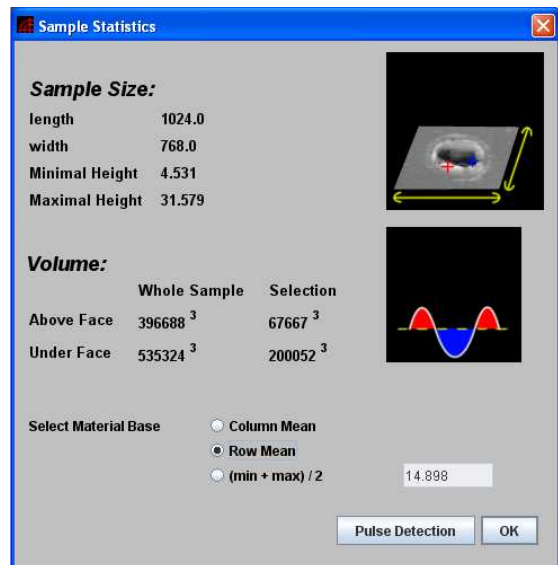


Figure 13. Statistics function - an example of results.

### C. Automatic Engraved Area Detection

These functions may not be useful for different types of height maps, but they can significantly speed up the exploration of laser engravings, where the material is modified by the laser beam in a single area. The algorithms used for these methods are described in [3][6]. The detection methods may be used for all height maps, but because they are designed for a specific type of height maps, the advisability for different height map types is disputable. All detection methods are available from the Pulse Detection menu. The user can choose from the following methods: statistical, spiral, or clipping. The result of these methods is a selection sized and positioned according to the result of the detection. It is also possible to run all the methods and to compare their results. This approach was used in [7], for instance, and is shown in Figure 14. There are also several other functions that can be used during data preprocessing and that work with semi-results of some of the detection methods.

### D. Height Map Comparisons

The second mode of the Height Map Viewer serves for comparing a pair of height maps. To visualize the differences, the 2D visualization mode is used. Both samples



should be opened at the same time and overlapped into the optimal and fitting position. The overlapping can be done automatically or by the user (the second sample can be moved by holding the Ctrl key).

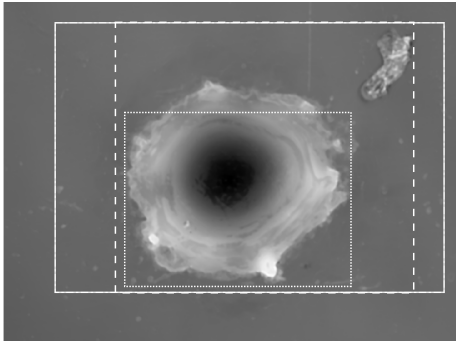


Figure 14. Comparison of results of all the detecting methods.

Finally, the samples can be visualized in three different ways - as both samples overlapped over each other (can be seen in Figure 16) or as the difference image in either linear or logarithmic scale [10] (Figure 15).

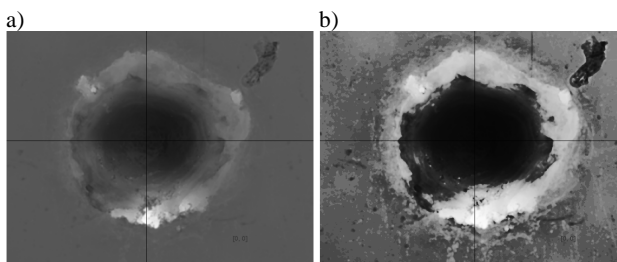


Figure 15. Comparison of two height maps: (a) difference image in linear scale; (b) difference image in logarithmic scale.

For either case, all the functions for exploring 2D visualization described above can be used and their results are adapted to the comparison mode. That means, if both height maps are shown together, the heights for both of them are shown and it is possible to measure differences between them. An screenshot of the comparison mode can be seen in Figure 16.

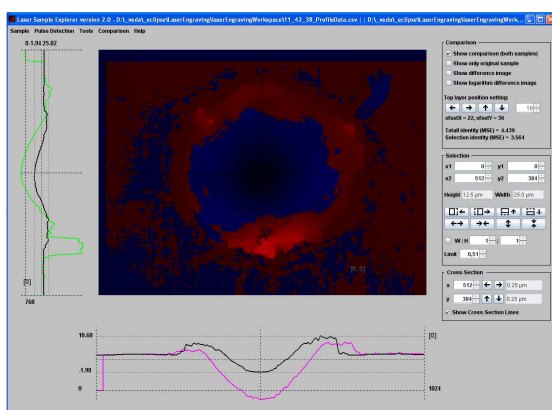


Figure 16. Visualization of compared height maps.

## V. CONCLUSION AND FUTURE WORK

The Height Map Viewer has been created to simplify exploring of height map surfaces and to enable to process height maps with a user friendly tool. It offers a broad range of functions for data processing and its export. The tool is used, among others, by the team of experts from the New Technology Center at the University of West Bohemia in Pilsen performing research in the area of lasers and helps them to explore laser-engraved samples measured by a confocal microscope.

The tool can be downloaded from [9]. However, thanks to the universal text-based input format, it can be also used for different purposes, where height maps need to be explored in detail. The functionality of the tool can be further extended in dependence on actual demands.

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