Software requirements

Experimental physics: “Analysis of interference images”

by “only-three-left” team of developers

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Introduction

1.1 Purpose of requirements document

This is a formal document created with the standard IEEE/ANSI 830-1998 (Recommended Practice for Software Requirements Specifications). The main purpose of this document is to specify all of the requirements for the system, which was created as the compulsory project to the subject “Development of the information systems” at the Faculty of Mathematics Physics and Informatics (UK BA). The requirements document is dedicated to all of the stakeholders. Moreover it can also work as an agreement between the developers and the client.

1.2 Scope of the product

The main goal is to create software for the Department of Experimental Physics at the Faculty of Mathematics Physics and Informatics (UK BA). Software will determine a bending/curving of samples from the images of the interference pictures, so we can reconstruct the shape of the sample.

1.3 Definitions, acronyms and abbreviations

I*nterference pattern* - consists of light reflected from surface A and light reflected from the bent sample B, which can result in a wave of greater, lower, or the same amplitude

Stakeholder - is anyone who influences or interferes with product development

GUI (Graphical User Interface) - it is a form of user interface that allows users to interact with electronic devices through graphical icons and audio indicators such as primary notation, instead of text-based user interfaces, typed command labels or text navigation.

1.4 References

- Github project repository
- Subject webpage
- Documentation archive
- Photo collection (including photo of samples and GUI mock-up)

1.5 Overview of the remainder of the document

In the remaining chapters of this document the reader will be informed about the system. Second chapter describes the perspective of the application and all functionalities.

General description

2.1 Product perspective

Product will be a graphical desktop application. After uploading or acquiring an input image, the application will be able to detect the radius of curvature of the sample once the user specifies the pattern center and line direction of measurement. A corresponding graph of intensity along the selected line will be shown as well.

2.2 Product functions

There are several product functions defined:

- Load images from filesystem or capture image from USB camera
- Allow user to upload a camera calibration config file from the filesystem
- Enable or disable the camera calibration
- Show the image
- Zoom the image
- Allow the user to define a line on the image (interference center and a point) and specify how many maximums user wants to see
- Generate clear interference graph
- Allow user to extend the width of the line, making it a circle sector, so that the generated graph gets cleaner by integrating the values acquired from this extension
- Calculate the radius of curvature of the sample
- Determine the maximum and minimum radius of curvature for all possible lines starting from the interference pattern center
- Allow user to generate point cloud document representing image, create .XYZ file

2.3 User characteristics

User of this software is a student or a university professor, who is doing a physical experiment in the laboratory, studying the interference. It is assumed that the software user has some basic physics knowledge in the field of interference. Nevertheless, the app interface and functions can be understood without it.

2.4 General constraints

It is assumed that the image uploaded to the program has a clear interference picture. This requires prior camera calibration and additional tools for camera fixing. Ideally the camera should be placed so that the plane of the camera sensor and the plane of the screen with the pattern are parallel, which leads to the more accurate calculations.

2.5 Assumptions and dependencies

This software requires a PC running it to have a JRE of version 8 installed and to have a standard I/O system. It is assumed that the input contains the interference image produced in the result of the physical experiment. Otherwise it is assumed that the user has a camera connected via USB port and that the captured image can be decoded by OpenCV library.

Specific requirements

3.1 Functional requirements

This section gives an overview of the specific functional requirements for the software. For better understanding of importance of any single requirement, we define three priority levels:

[P1] - High priority
[P2] - Medium priority
[P3] - Low priority

3.1.1 *[P1]* Option to read image from filesystem

User can select the option to load the image from the filesystem via the common FileChooser Dialogue window. This image is then to be displayed to the user, allowing him to do measurements on it.

3.1.2 *[P1]* Option to read image from camera

A user can select the option to capture the image via the connected camera using a camera preview on/off switch. When the switch is off, the preview is stopped and the last image retrieved from the camera can be analyzed. This image remains displayed to the user, allowing him to do measurements on it. After switching the preview switch on, the image is overdrawn by new frames from the camera.

3.1.3 *[P1]* Specify the center of an interference pattern

A user can select the option to select a pixel in the interference pattern shown in the window using a mouse pointer. This pixel will be considered to be the center of the interference pattern in the forthcoming calculations.

3.1.4 ***[P1]* Specify the target point of the line segment for calculations**

A user can select the option to choose the second point of the line segment where measurement is to be done. The first one [3.1.3] must be located in the center of the pattern, the second one is an arbitrary pixel.

3.1.5 ***[P1]* Specify the reference line segment in the interference pattern**

A user can select the option to use the mouse pointer to select the starting and final points of a reference line segment in the interference pattern image. The measured length in pixels is shown in an edit box and can be entered by the user also manually. The reference line length in pixels is then used to recalculate the pixel/mm ratio together with the input in 3.1.6.

3.1.6 ***[P1]* Assign the length to the reference line segment**

A user can specify the length (in the input box) of the reference line segment in millimeters.
These two values (3.1.5 and 3.1.6) are then used for radius calculations.

3.1.7 ***[P1]* Limit the number of maximus to find**

The user can specify an upper limit on the number of maximums to detect on the selected line segment. After the specified limit is reached, further maximums will not be searched for.

3.1.8 ***[P1]* Produce the graph**

After the user selects the line segment, the graph showing pixel intensity along the selected line segment is automatically shown in the graph area in the main user interface window. User has an option to smoothen the graph by adjusting the width of the line if the image is not clear enough. The graph visualizes the detected maximum extreme points.

3.1.9 ***[P1]* Analyze maximums and minimums of the graph to get radius**

With the use of the information received from the image and programmed formulas the app is able to calculate the radius of the interference for any two consecutive maxima detected on the selected. It produces a list of such radiuses up to the limit specified (3.1.7) or the number of detected maxima on the line segment. All of these values are then presented to the user in the text area (3.1.16).

3.1.10 ***[P3]* Calculate maximum and minimum radius**

After the interference image has been received by any input source the user can select the option to calculate the radius of curvature of the sample for every possible line defined from the center of the interference, iterating by angular step specified by the user in a separate edit box. The user is then presented with the result consisting of the following values: maximum interference radius and minimum interference radius and the angles under which they were found. The lines representing the two directions of measurement are then drawn on the image and labeled with these values.

3.1.11 *[P3]* Export PNG image

The user can at any time select an option to save the currently shown image of the interference pattern including the marked line segment, or minimal and maximal sample radius directions in PNG format.

3.1.12 *[P3]* Simple user manual

Either in-app manual or external documentation describing the app's workflow will be accessible from the software.

3.1.13 *[P1]* Camera calibration configuration file

Software provides an option to load the camera calibration file from the filesystem. User then can enable or disable it.

3.1.14 *[P2]* Perform sweep measurement to obtain a point cloud

The user has an option to start an automatic sweep of the whole interference pattern along lines going from the specified pattern center in all possible directions (using an angular step specified in an edit box). For each direction, all the consecutive pairs of maxima up to the specified limit will produce one point [X,Y,Z], which is determined from the radius of the curvature of the sample for that particular pair of maxima. The resulting point cloud - the x, y and z coordinates of such 3D points are saved to a ".xyz" data specified by the user.

3.1.15 *[P1]* Additional experimental parameters

Let user insert parameters based on which we will calculate: user might need to input parameters of laser setup (distances between laser, sample, camera etc). In particular these are:
D [mm] - the distance between the sample and the screen with the pattern
lambda [nm] - the wavelength of the laser

3.1.16 *[P1]* Text report from the experiment

The main user interface window will contain a text area where the program will output and append all important values during the experiment, i.e. the coordinates of the center of the interference pattern, the selected target point of the analyzed line segment, reference line length in pixels and millimeters, the coordinates of the detected maxima, the calculated radiuses for each pair of the maxima, angles for the minimum and maximum radius, and all other important values. This text output is automatically appended to a text file including timestamps.

3.2 Non-functional requirements

In this chapter we are talking about specifications that describe the system’s operation capabilities and constraints that enhance its functionality. Simply said, the requirements that describe operational qualities rather than the behavior of the product.

3.2.1 Performance

The software does not include any unnecessary artificial delays. Performance delays are minimised as much as possible.

3.2.2 Portability and compatibility

The software is compatible with most popular operating systems. The software does not have any specific hardware requirements, so it can be deployed on every modern PC. Portability is available through Docker image system.

3.2.3 Reliability and availability

Software processes any possible exception occurred, making its run flawless for the user. No app crashes are expected and tolerated, which means the app is available to the user for its full operational time.

3.2.4 Maintainability

Modularity and clean code structure of the software makes it easily maintainable. The app supports small and effective patch flow.

3.2.4 Security

There is no additional security layer defined as the operating data is not personal, so the app doesn’t have to be protected against malware attacks or unauthorized access.

3.2.5 Localization

Software does not support any localization features. English was chosen as a primary language for any outputs provided by the software as it is the common international tongue.

3.2.6 Usability

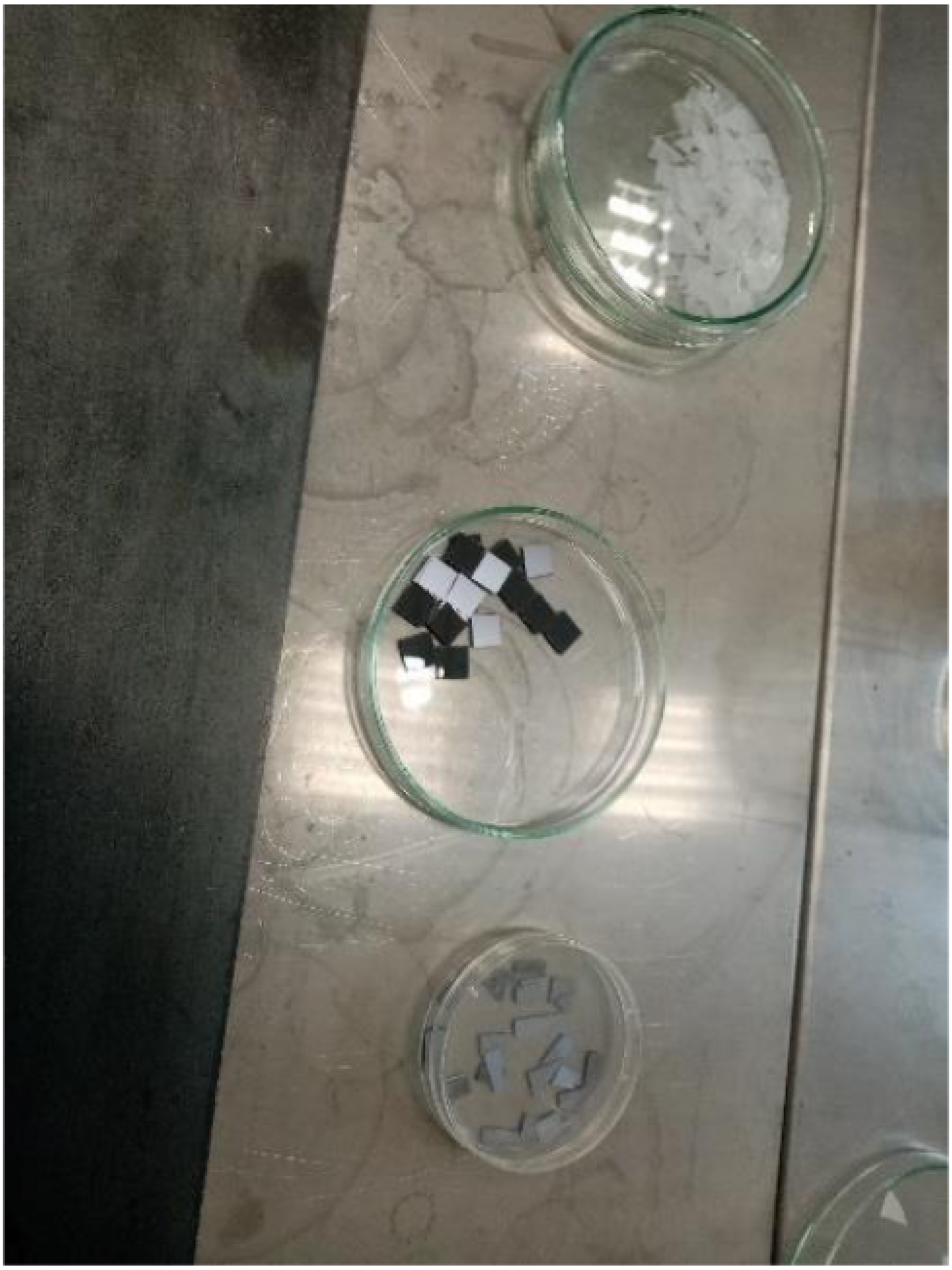
All app features are easily accessed through interface elements. Overall GUI solution is user-friendly and requires minimum additional knowledge. Interface is rather intuitive and uses a calm and pleasant color scheme.

3.3 Interface requirements

The placing and the purpose of every GUI element is described in detail in GUI design documentation in close collaboration with the client.

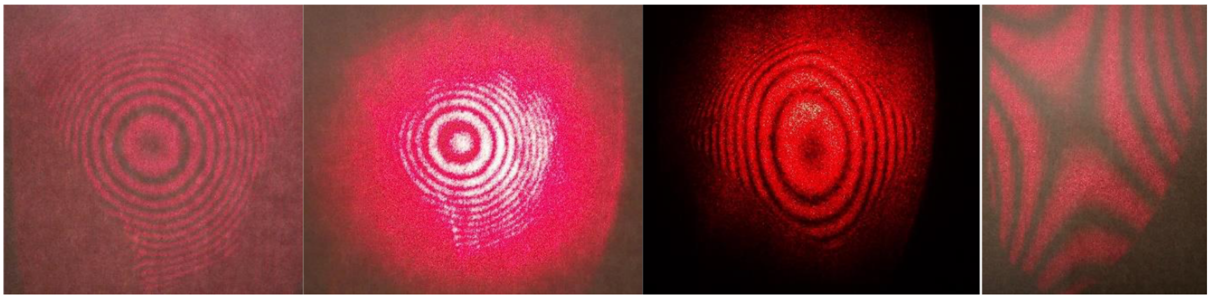
Appendices

4.1 Actual samples, subjects of the experiments

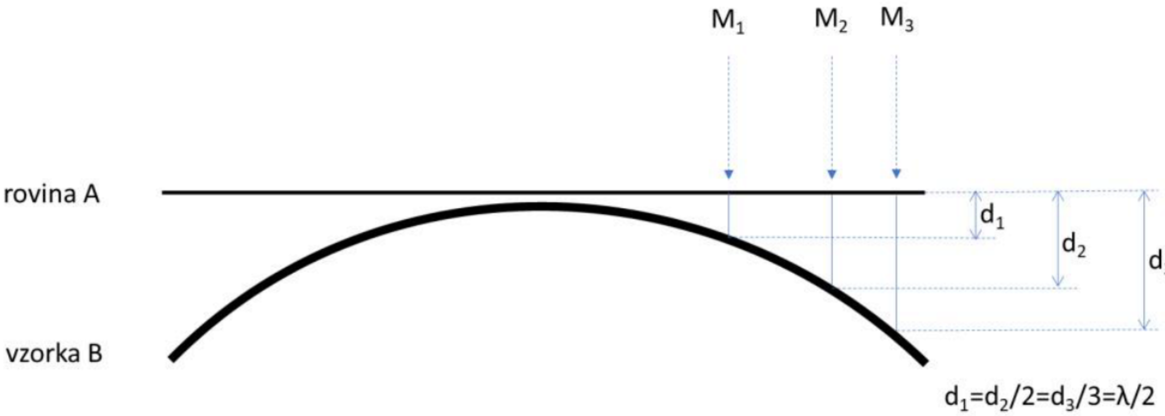


4.2 Laboratory, where the experiments are being performed

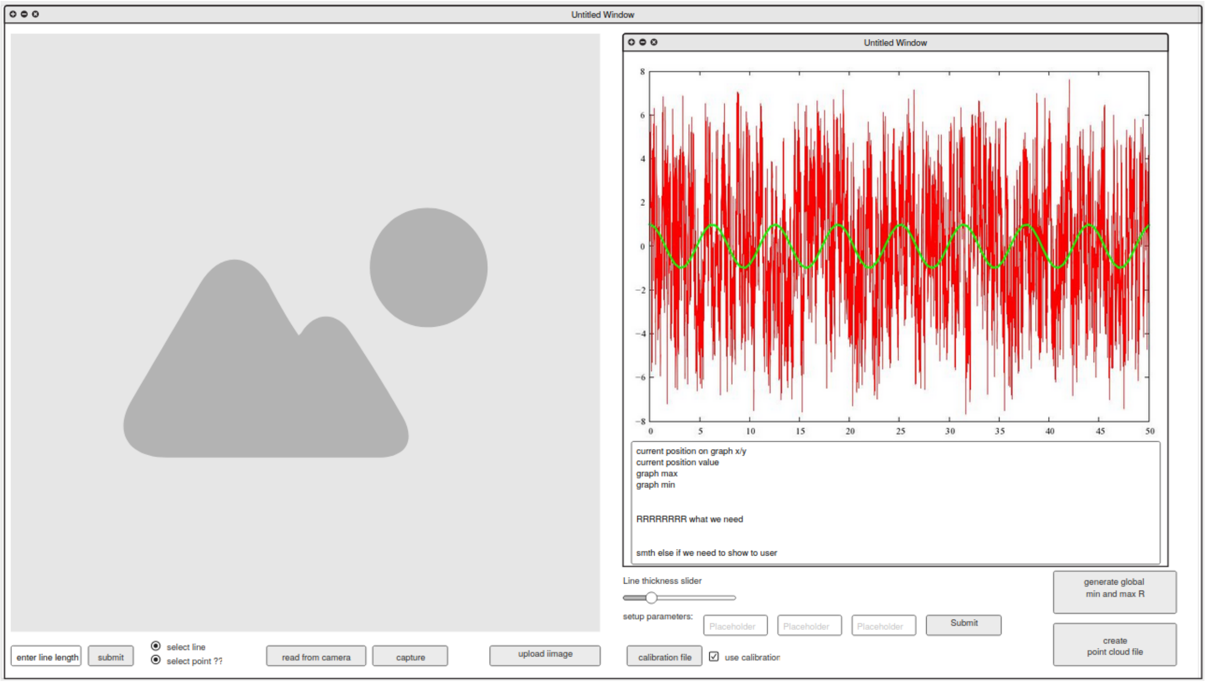
4.3 Examples of interference images



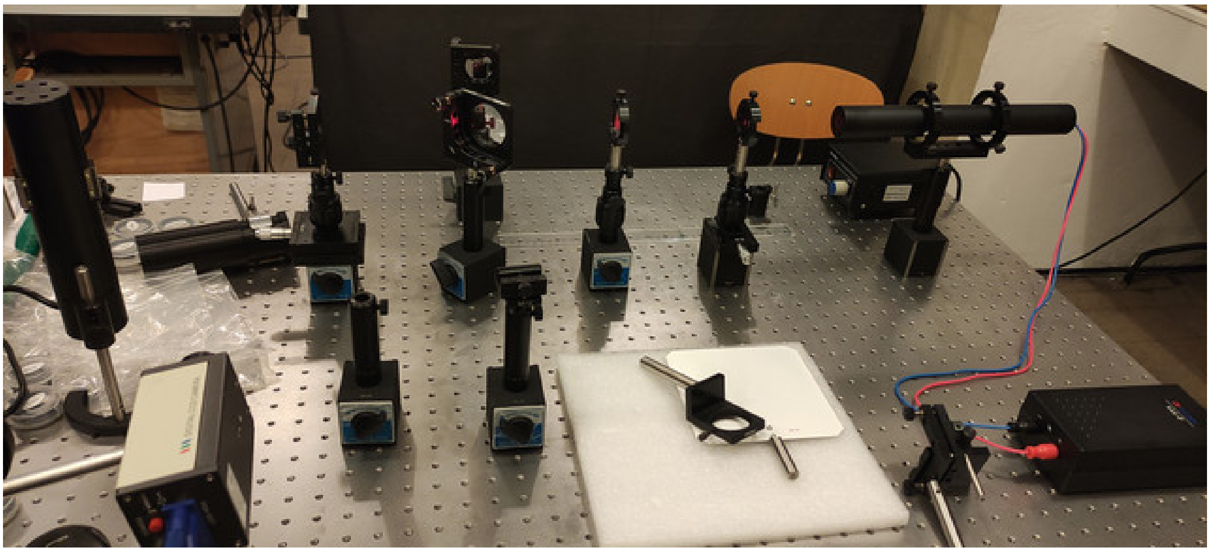
4.4 Geometry of the interference image experiment



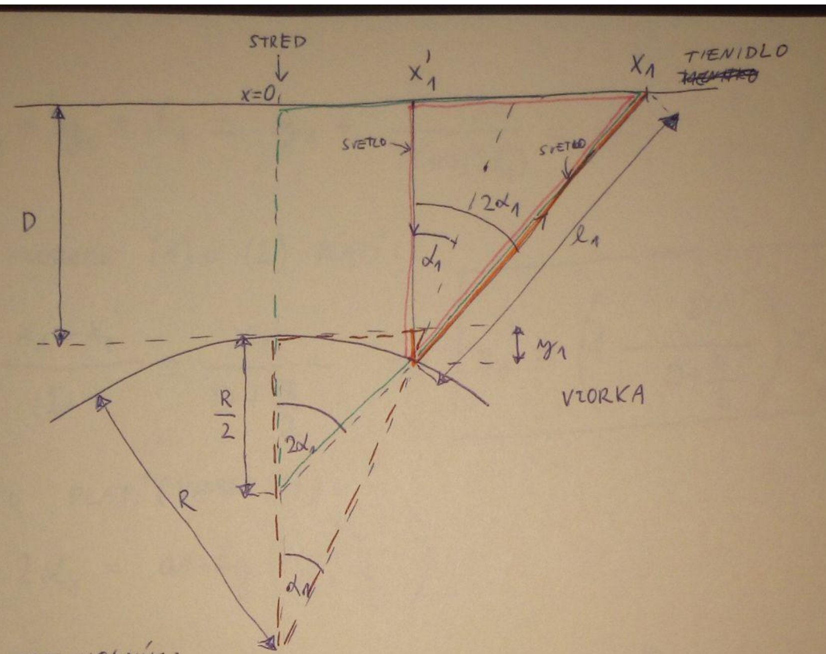
4.5 GUI mock-up



4.6 Actual measuring set-up



4.7 Formulas



ZELENÝ TROJUHOLNÍK:

$$\boxed{\frac{x_1}{D+\frac{R}{2}} = tg(2\alpha_1) \quad (1)}$$

; $\frac{R}{2}$ je vo vzorci ako aproximácia – platí to len pre malé α_1 – čo je náš prípad

RUŽOVÝ TROJUHOLNÍK:

$$\frac{x_1 - x_1'}{D + y_1} = tg(2\alpha_1)\ ; \ y_1 << D \Rightarrow \boxed{\frac{x_1 - x_1'}{D} = tg(2\alpha_1) \quad (2)}$$

HNEDÝ TROJUHOLNÍK (PRIBLIŽNÝ VZOREC):

$$\boxed{y_1 = R - \sqrt{R^2 - x_1'^2} \quad (3)}$$

ZAUJÍMA NÁS DRÁHOVÝ ROZDIEL $\Delta_1 = y_1 + l_1$ (ORANŽOVÁ)

PRIČOM:

$$l_1 = \frac{D + y_1}{\cos(2\alpha_1)}$$

$$\Delta_1 = y_1 + l_1 = y_1 + \frac{D + y_1}{\cos(2\alpha_1)} = y_1\left(1 + \frac{1}{\cos(2\alpha_1)}\right) + \frac{D}{\cos(2\alpha_1)}$$

ZO VZORCOV (1) a (2) PLATÍ:

$$\frac{x_1 - x_1'}{D} = \frac{x_1}{D + \frac{R}{2}} \Rightarrow \boxed{x_1' = \left(1 - \frac{D}{D + \frac{R}{2}}\right) x_1 \quad (4)}$$

TAKISTO PLATÍ (VZOREC (1)):

$$2\alpha_1 = \operatorname{arctg}\left(\frac{x_1}{D + \frac{R}{2}}\right)$$

$$\cos(2\alpha_1) = \cos\left(\operatorname{arctg}\left(\frac{x_1}{D + \frac{R}{2}}\right)\right) = \frac{D + \frac{R}{2}}{\sqrt{x_1^2 + \left(D + \frac{R}{2}\right)^2}}$$

ČIŽE

$$\Delta_1 = \left(R - \sqrt{R^2 - x_1'^2}\right) * \left(1 + \frac{\sqrt{x_1^2 + \left(D + \frac{R}{2}\right)^2}}{D + \frac{R}{2}}\right) + \frac{D\sqrt{x_1^2 + \left(D + \frac{R}{2}\right)^2}}{D + \frac{R}{2}}$$

$$\boxed{\Delta_1 = \left(R - \sqrt{R^2 - \left(1 - \frac{D}{D + \frac{R}{2}}\right)^2 x_1^2}\right) * \left(1 + \frac{\sqrt{x_1^2 + \left(D + \frac{R}{2}\right)^2}}{D + \frac{R}{2}}\right) + \frac{D\sqrt{x_1^2 + \left(D + \frac{R}{2}\right)^2}}{D + \frac{R}{2}}}$$