User Guide

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Version 1.0

GD4Shapes v1.0 USER GUIDE

GD4Shapes Matlab Package

Software to obtain geodesic distances with fixed parametrization for 2D Shapes

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1 Introduction

1.1 Scope and Purpose

Shape analysis within the **shape space** provides a robust framework for examining the geometric properties of objects in images, such as contours, dimensions, and spatial relationships. This approach is widely applied in image analysis to identify patterns, segment structures, and measure deformations, making it invaluable in fields like medicine, biology, and computational geometry. By focusing on how shapes are structured and interact in their spatial context, shape analysis allows for precise classification and evaluation of objects based on their geometry.

One of the core tasks in shape analysis is determining the geodesic distance between two shapes within the shape space. This metric provides a quantitative measure of similarity or difference between shapes, critical for classification and comparison. Traditionally, this calculation requires an iterative process that explores all possible parametrizations of one of the shapes, selecting the smallest distance obtained as the geodesic distance. While this method is accurate, it is computationally intensive and time-consuming, limiting its practicality for large-scale or time-sensitive applications.

GD4Shapes offers a streamlined approach to computing geodesic distances between two closed plane curves in shape space. Instead of relying on an iterative parametrization process, the software aligns the curves along their major axes and applies a fixed parametrization. This eliminates the need for exhaustive iterations, significantly reducing computation time while maintaining a result that closely approximates the true geodesic distance. The fixed parametrization methodology ensures high accuracy, making the software an effective tool for shape classification tasks.

The geodesic distances calculated by **GD4Shapes** provide a robust metric for shape-based analysis and classification. In medical imaging, this metric can be used to distinguish normal erythrocytes from sickle cells and to study the process of cellular deformation as red blood cells transition from their typical biconcave shape to elongated, rigid forms [1]. In botanical studies, it enables the comparison of leaf contours for species classification [2]. Similarly, in aquatic research, it supports the identification of fish species based on shape [3]. While the software focuses on distance computation, this metric serves as a foundation for diverse shape analysis applications.

1.2 Process Overview

GD4Shapes offers a streamlined approach to computing geodesic distances between two closed plane curves in shape space.

A typical sequence for using the software to manage functions:

1. Configure your workspace
2. Manage a key workflow
3. Troubleshoot

2 Configure your workspace

GD4Shapes is compatible with MATLAB version 2021a and later.

How to install

1. Open Matlab.
2. Go to APP tab.
3. Click on the "Install App" button.
4. Select the GD4Shapes.mlapp install file.
5. In the Install dialog click on the "Install" button.

How to run

Type in the Matlab command window:

>> GD4Shapes<Enter>

or find GD4Shapes in the APP tab of Matlab.

Original data

The installation package includes sample curves for use with the software. Users can analyze their own curves or utilize the sample curves provided within the package.

Input curves must be stored in a `.mat` file containing a 2xN array, where **N** represents the number of points in the curve. In the array, the first row corresponds to the **X-coordinates**, and the second row corresponds to the **Y-coordinates**.

3 Manage workflows

Functionalities

- Load the curves to be analyzed.
- Compute the geodesic distance between the curves.
- Visualize the original curves, aligned curves, computed distance, and geodesic paths.
- Export the graphs of interest as needed.

3.1 Loading the curves to be analyzed

GD4Shapes allows to load the curves to be analyzed. The interface has two buttons that give access to an open dialog, to choose the file that corresponds to each of the curves (Figure 1).

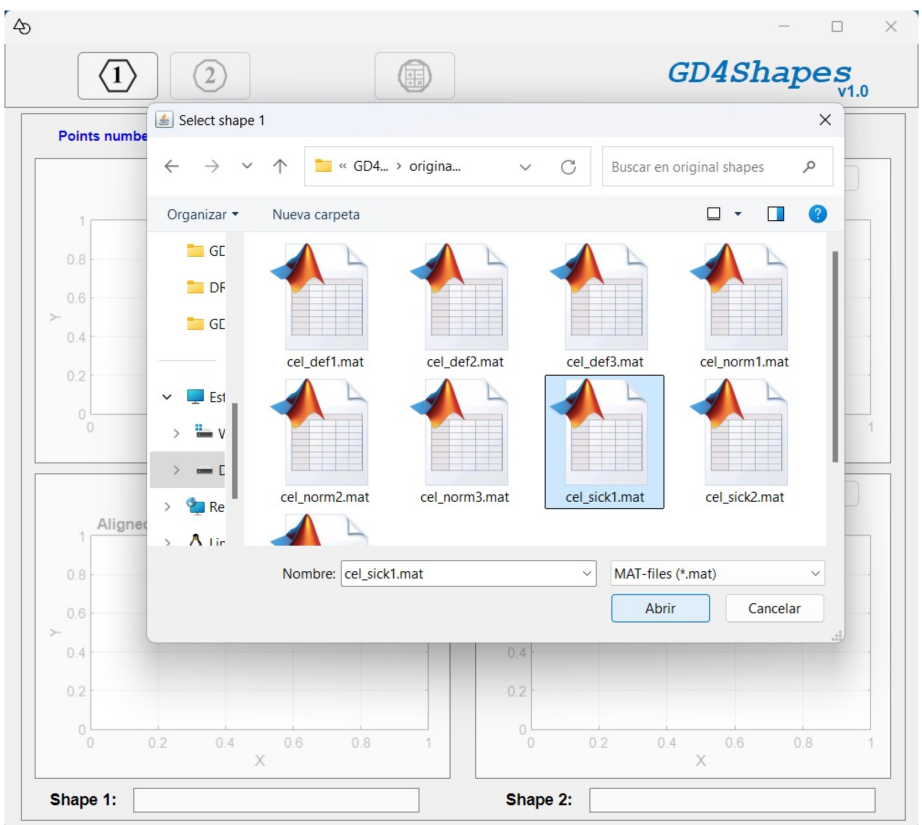

Figure 1. Loading the first curve.

When the two curves to be processed are loaded, information regarding the name of the loaded file and the number of points in the curve is updated in the interface. This information is differentiated by color: blue corresponds to the first curve, red corresponds to the second. The curves are plotted on the first graph that the tool displays (Figure 2). The starting point of the contour parametrization is shown for each of the curves.

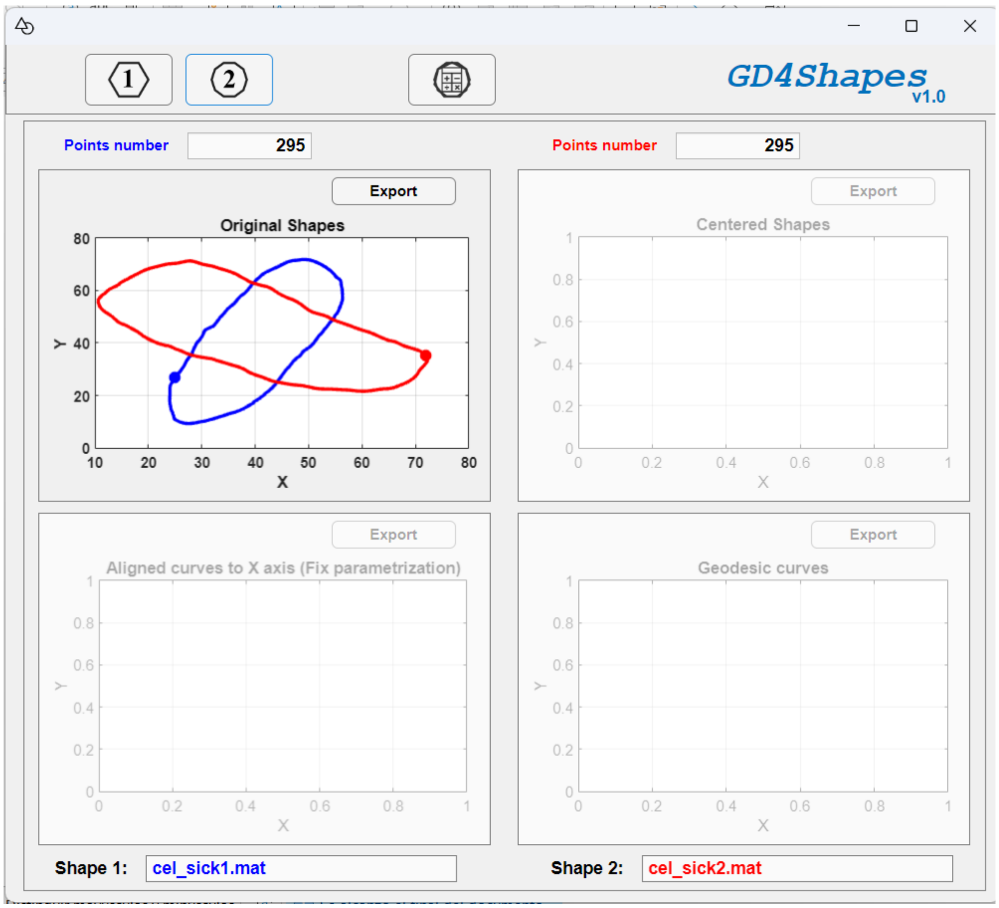

Figure 2. The original curves are plotted.

3.2 Compute the geodesic distance between the curves

When both curves are loaded, the button that allows processing is activated (highlighted in black in the Figure 3). For processing, it is necessary to define the number of points that will be considered for the initial curves and the number of curves of the obtained geodesic that will be displayed. By default, a value equal to twice the number of points of the longest curve is proposed. This value can be changed by the user, who must take into account that the greater the number of points, the greater the processing performed (Figure 3).

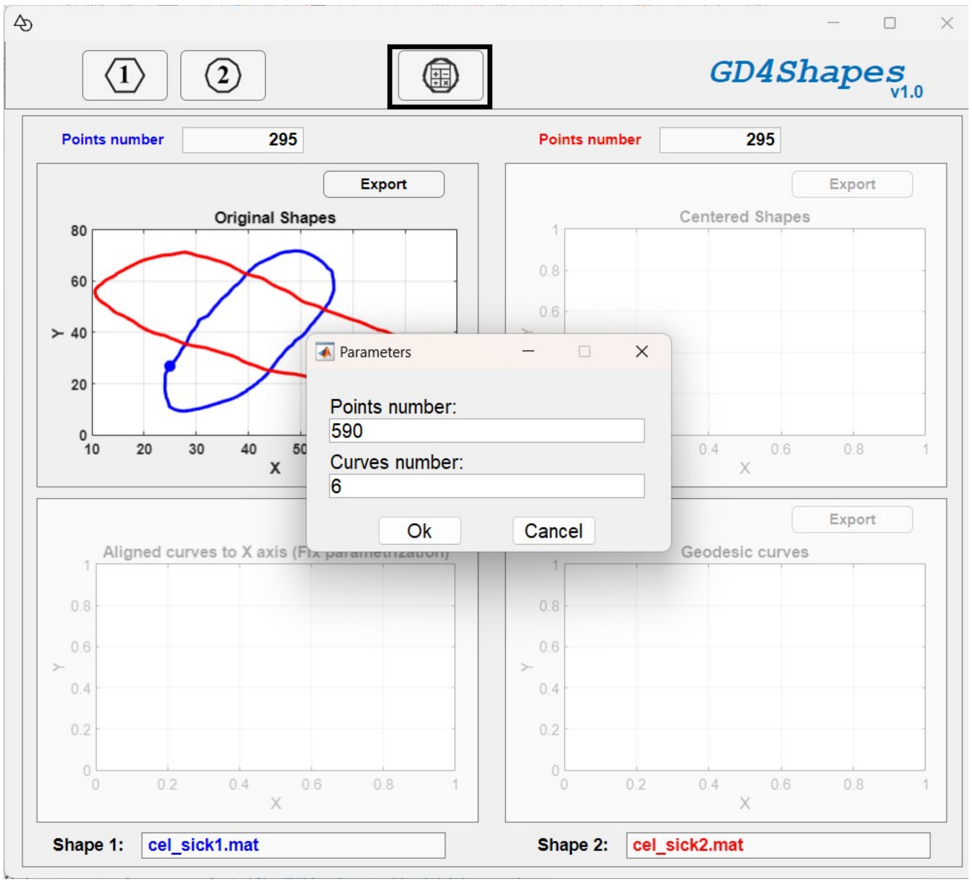

Figure 3. Defining number of points for the process and number of curves of the obtained geodesic.

To compute the geodesic distance, both curves are first translated to the origin of the coordinate system based on their centroids. Next, the curves are aligned along their major axes, with the contour point intersecting the positive X-axis designated as the initial point of parametrization. This fixed parametrization is then used to compute the geodesic distance. The interface displays a message to communicate that processing is taking place.

3.3 Visualizing and exporting the results

The tool graphically displays all the steps required for calculating the distance: the curves centered on the origin; the curves aligned according to their major axis, and their parametrization fixed according to the applied methodology, with the initial point of the contour for each curve; and finally the curves of the geodesic obtained (Figure 4).

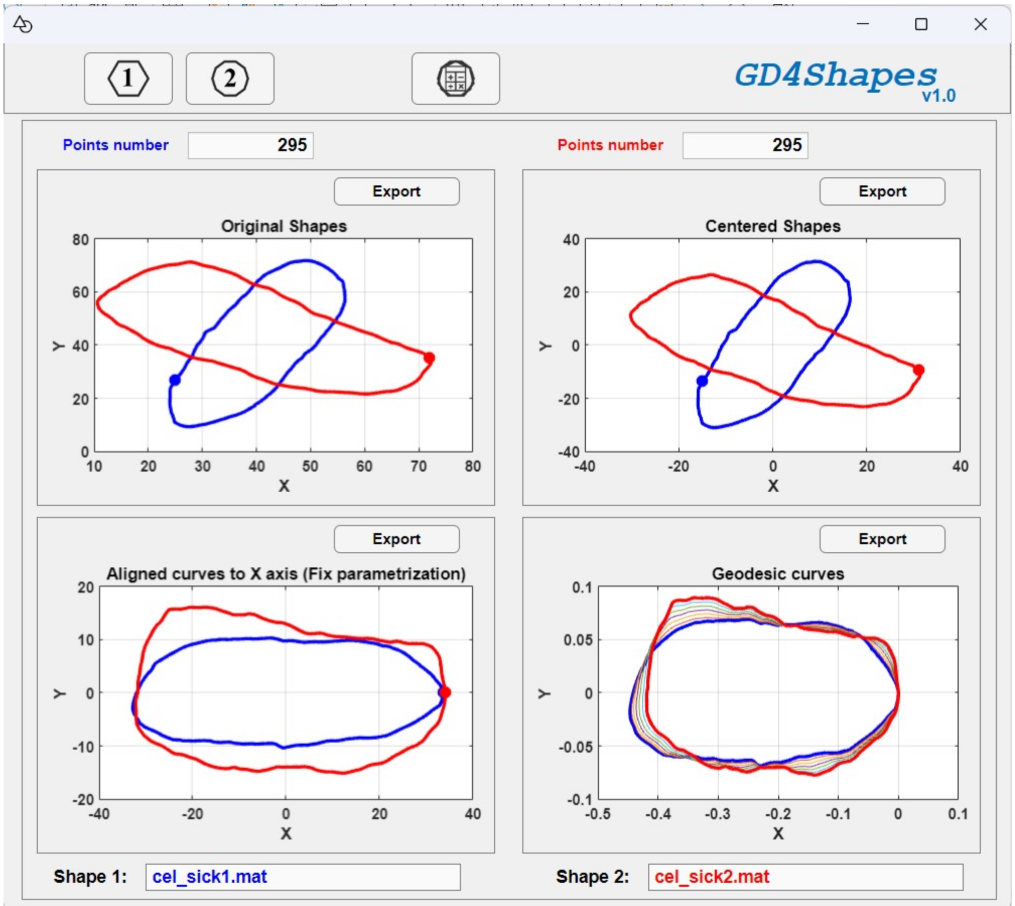

Figure 4. Visualizing the results of the process.

In addition, the value of the geodesic distance between both curves is displayed in a pop-up window (Figure 5).

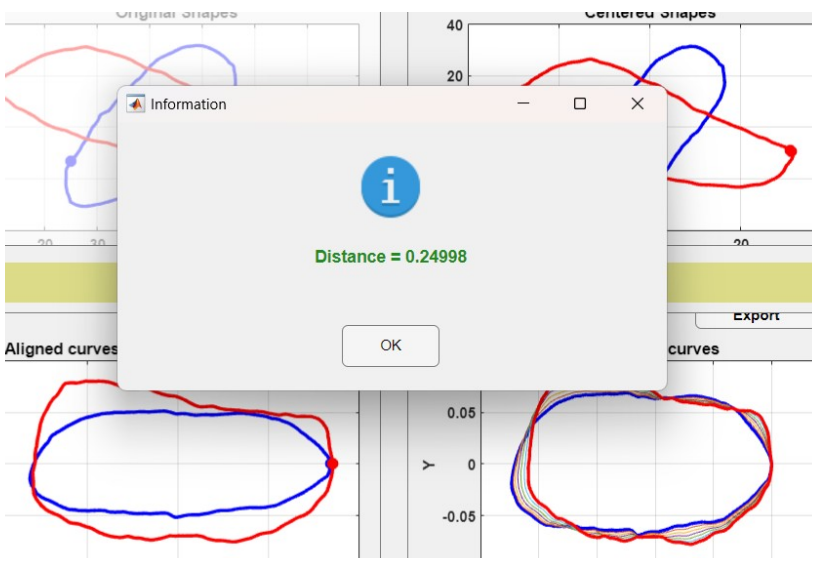

Figure 5. Geodesic distance obtained.

All generated graphics can be exported to the following formats: jpg, png, tiff and pdf. All generated graphs can be exported to the following formats: jpg, png, tiff and pdf. The tool provides an Export button on each graph for this functionality, which when clicked displays a dialog box to determine the path, type and name of the file to be exported (Figure 6). The interface displays a message to communicate that exporting is taking place.

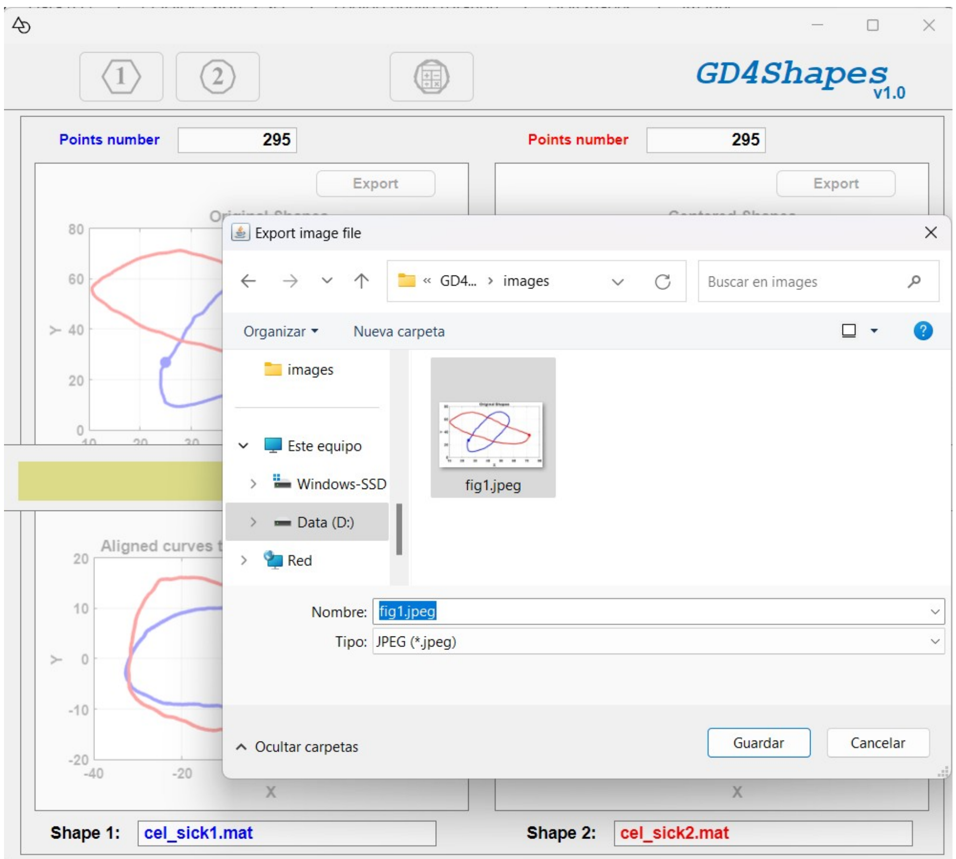

Figure 6. Exporting figures.

4 Troubleshoot

The distance is obtained between different curves. If two identical curves are entered, the tool will issue an information message about this and will not perform any processing. The second curve is shown in red with dashed lines (Figure 7).

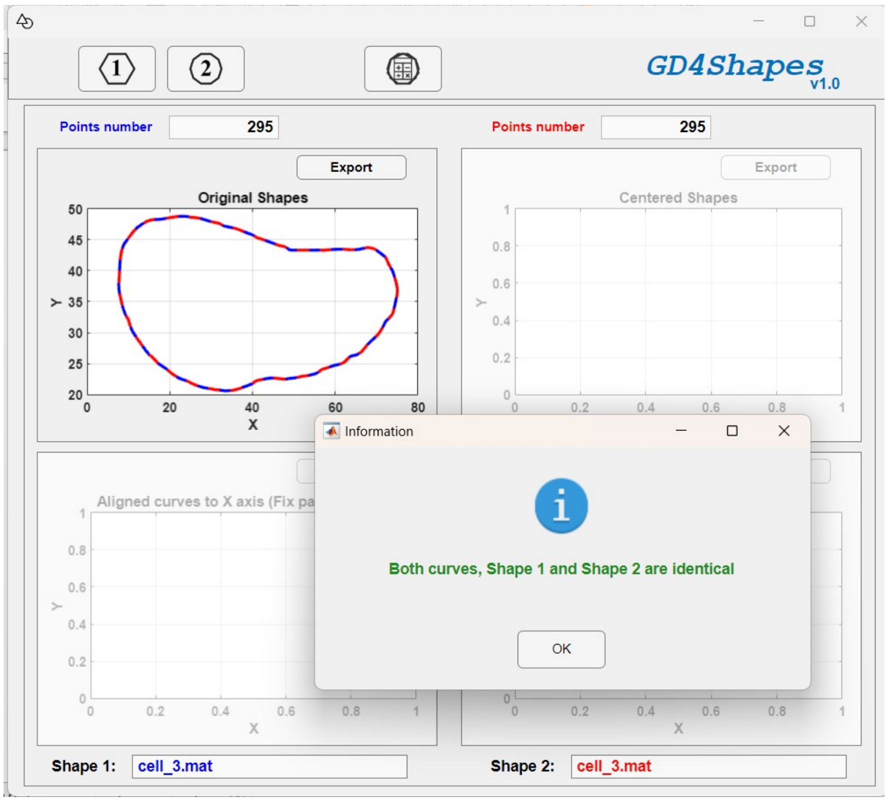

Figure 7. Both curves are identical.

Curves that can be analyzed must be plane, so their representation matrix has dimensions 2xN, where N is the number of points of the curve. If the first dimension of the matrix representing the curve is not 2, the tool issues an error message (Figure 8).

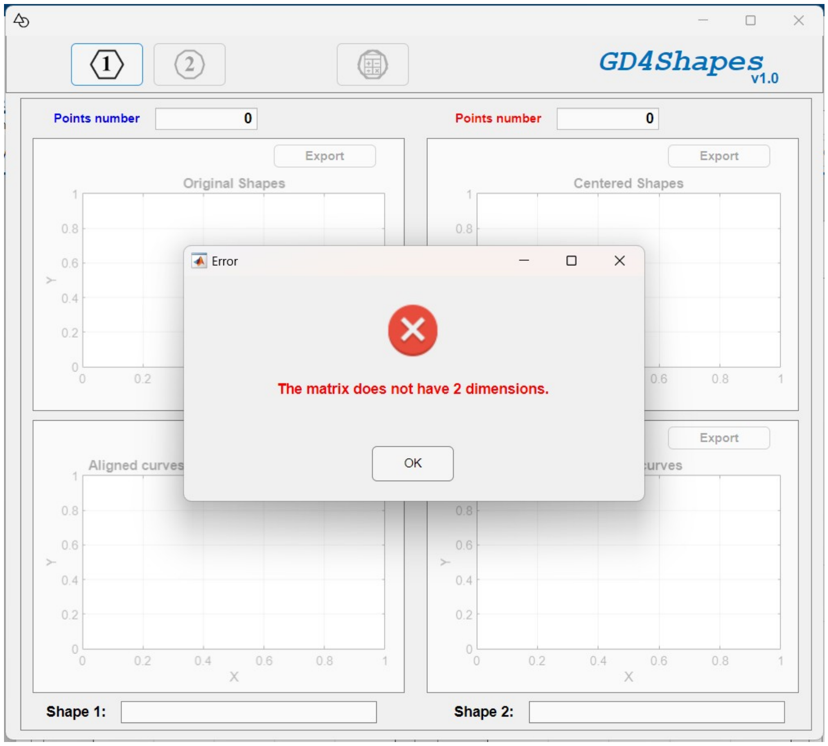

Figure 8. Error message: The matrix does not have 2 dimensions.

In case the user wants to change one of the two originally loaded curves, the interface will reset all associated graphs, and the processing must be performed again.

The tool checks whether the input corresponding to each curve is valid, verifying whether it is a Matlab file and whether it has internal information. If this is not the case, an error message is issued (Figure 9).

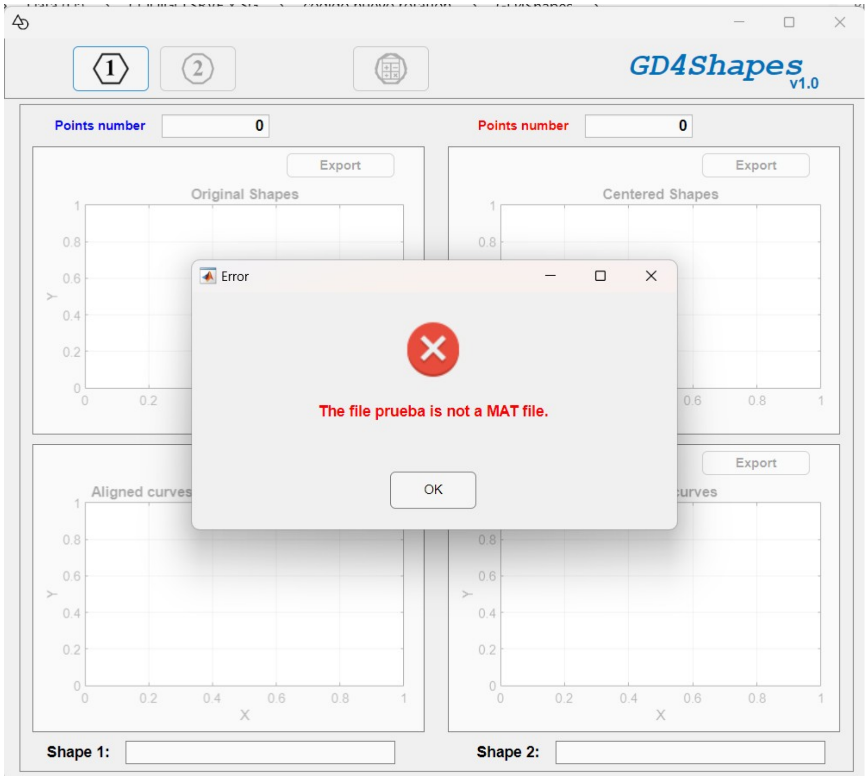

Figure 9. Error message: The file is not a MAT file.

5 References

[1] I. Epifanio, X. Gual Arnau, S. Herold Garcia. Morphologycal analysis of cells by means of an elastic metric in the shape space. Image Anal Stereol 39 (2020) 281–291. DOI: https://doi.org/10.5566/ias.2183

[2] H. Laga, S. Kurtek, A. Srivastava, M. Golzarian and S. J. Miklavcic. A Riemannian Elastic Metric for Shape-Based Plant Leaf Classification, 2012 International Conference on Digital Image Computing Techniques and Applications (DICTA), Fremantle, WA, Australia, 2012, pp. 1-7, doi: 10.1109/DICTA.2012.6411702.

[3] M. Bauer, M. Bruveris, P. Harms, and J. Møller-Andersen, J. (2015). Second order elastic metrics on the shape space of curves. In H. Drira, S. Kurtek, & P. Turaga (Eds.), Proceedings of the 1st International Workshop on DIFFerential Geometry in Computer Vision for Analysis of Shapes, Images and Trajectories (DIFF-CV) 2015 (pp. 1-11). BMVA Press. https://doi.org/10.48550/arXiv.1507.08816