# PERFORMANCE EVALUATION OF 2D IMAGE REGISTRATION ALGORITHMS WITH THE NUMERICS IMAGE REGISTRATION AND COMPARISON PLATFORM

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**Abstract**

*The objective of this work is to present the capabilities of the NUMERICS web platform for evaluation of the performance of image registration algorithms.*

*The NUMERICS platform is a web accessible tool which provides access to dedicated numerical algorithms for registration and comparison of medical images (http://numerics.phys.uni-sofia.bg). The platform allows comparison of noisy medical images by means of different types of image comparison algorithms, which are based on statistical tests for outliers. The platform also allows 2D image registration with different techniques like Elastic Thin-Plate Spline registration, registration based on rigid transformations, affine transformations, as well as non-rigid image registration based on Möbius transformations. In this work we demonstrate how the platform can be used as a tool for evaluation of the quality of the image registration process.*

*We demonstrate performance evaluation of a deformable image registration technique based on Möbius transformations. The transformations are applied with appropriate cost functions like: Mutual information, Correlation coefficient, Sum of Squared Differences. The accent is on the results provided by the platform to the user and their interpretation in the context of the performance evaluation of 2D image registration.*

*The NUMERICS image registration and image comparison platform provides detailed statistical information about submitted image registration jobs and can be used to perform quantitative evaluation of the performance of different image registration techniques.*

## Introduction

The NUMERICS platform is an online toolkit for medical image processing. The platform provides access to dedicated numerical algorithms for image comparison and image

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registration. The algorithms are specifically designed for application to noisy medical images. The platform offers an intuitive and user-friendly web interface for uploading images and selecting the parameters and the components of the requested image processing job. Submitted jobs are processed server-side and the obtained results from the calculations are displayed back to the user via a compact graphical interface (hereafter called "dashboard"). The dashboard provides the user with detailed statistical results for each of the intermediate steps of the performed calculation. This information can be used to quantitatively evaluate the performance of the selected image processing algorithms.

The focus of this work is on the application and evaluation of the performance of the image registration algorithms that are integrated in the NUMERICS platform. We present the necessary steps required to submit an image registration job to the platform and then we discuss the meaning of the obtained results.

**Materials and Methods**

All of the algorithms implemented in the NUMERICS platform currently operate with 2D images. There are two general categories of image registration algorithms available on the platform – "Standard" and "Elastic Thin-Plate Spline" (TPS) image registration.

The image registration algorithms in the standard category are based on the parameter optimization technique in which the user specifies a family of geometry transformations, a cost function and an optimization algorithm. The available geometry transformations on the NUMERICS platform are: rigid (translations and rotations only), affine (translations, rotations, scaling, shearing and reflection) and Möbius transformations (for more information about the Möbius transformation approach, see Ref. [1]). The available cost functions on the platform are: Sum of Squared Differences (SSD), Cross-Correlation (CC) and Mutual Information (MI). The user can choose between the following optimization algorithms: Levenberg-Marquardt Algorithm (LMA), Broyden-Fletcher-Goldfarb-Shanno (BFGS) method and the Nelder-Mead downhill simplex method.

The TPS image registration algorithm available on the NUMERICS platform is based on the thin-plate splines interpolation approach, which has been introduced in medical image analysis by Bookstein [2]. In this approach the elastic deformation of the initial image is performed by interpolating feature point displacements in the coordinate plane using thin-plate splines. In the current implementation, the feature points in the two registered images are automatically detected and matched by a dedicated preprocessing algorithm.

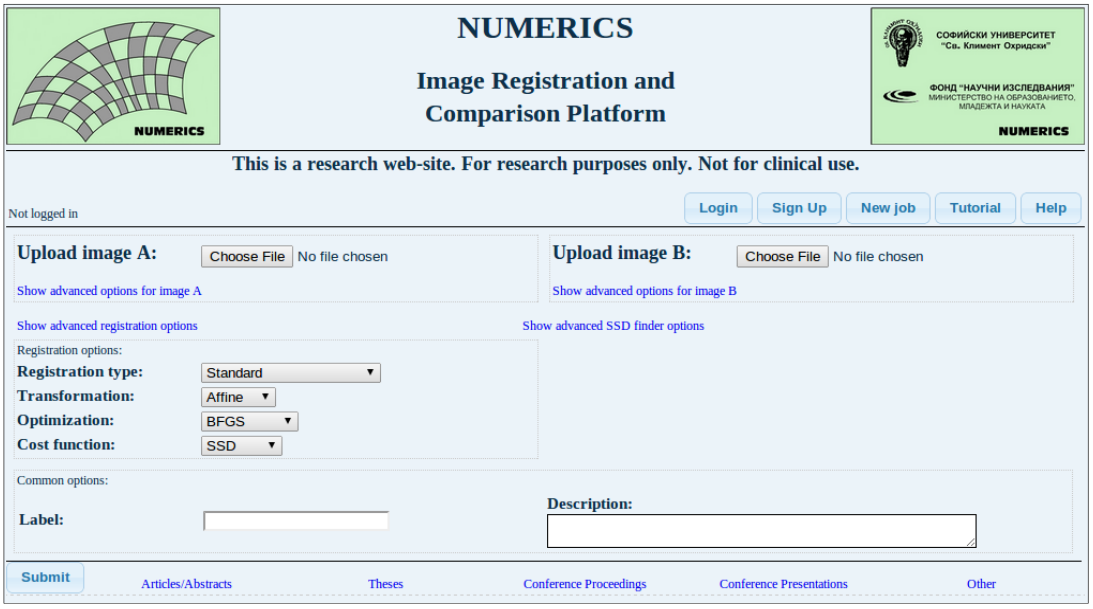


Figure 1. The front page of the NUMERICS platform. On this page the user uploads the two images that are to be registered. The user also specifies the type and the parameters of the algorithms that will be used.

Figure 1 shows the front page of the NUMERICS platform. On this page the user uploads the two images that will be registered. The platform supports the DICOM file format, as well as some of the most commonly used image file format types. After the images are selected, the user selects the image registration options in the "Registration options" section and submits the job for processing. The obtained results for the submitted job are displayed back to the user on a separate page (see Fig. 2). On this page, the dashboard gives the user access to the results from the intermediate steps of the selected image registration algorithm. For example, the user can choose to see the originally submitted images – image A and image B, the registered image A, the difference image A-B before and after the registration, etc. For each image the user can click on the "Image statistics" button in the upper-right corner of the dashboard to get detailed statistical information about the pixel intensities in the selected image. The statistical information includes: mean, median, maximum and minimum intensity, standard deviation of the intensities, 3-rd and 4-th moment of the distribution of the intensities and a histogram of the intensity distribution. The dashboard also provides some additional processing operations that are useful for analyzing the results – rendering of contours that visualize areas of statistically significant differences between the two submitted images and displaying the images in different color schemes, in order to improve the visualization quality.

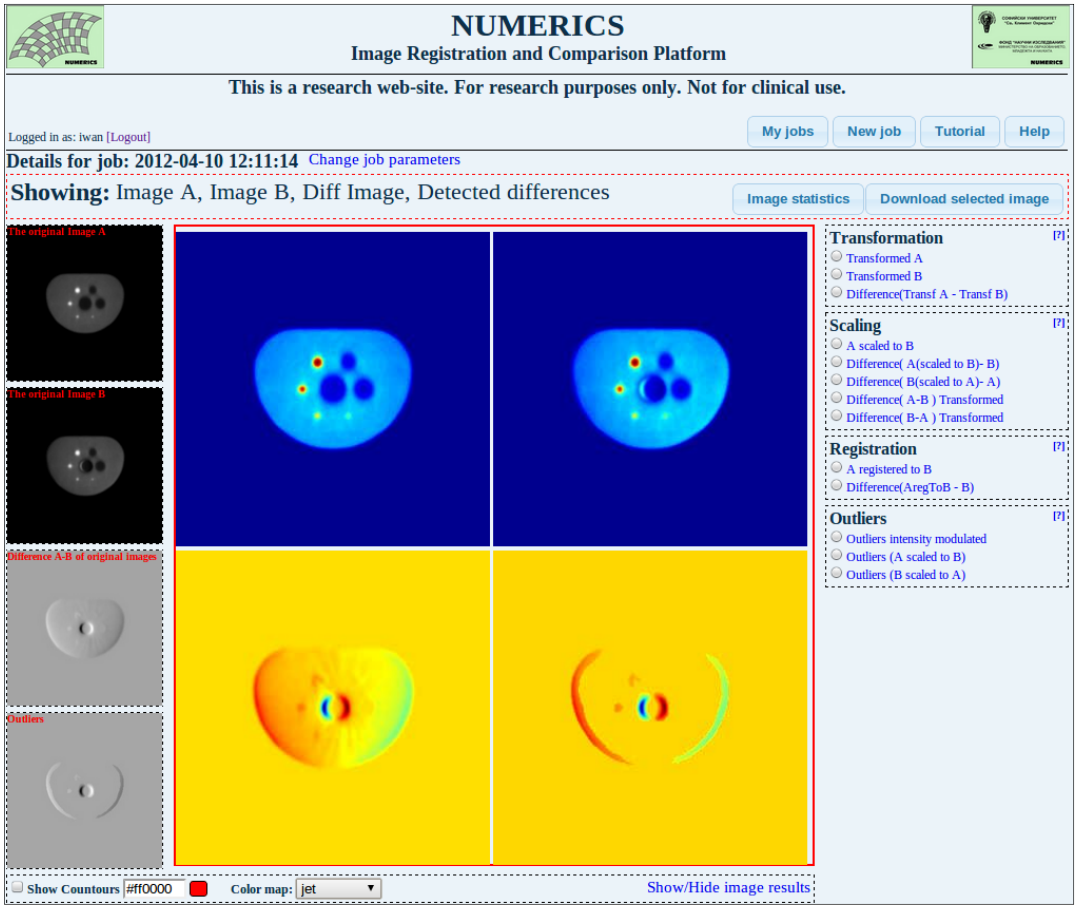


Figure 2. An overview of the dashboard containing the results from a submitted job. On the right side of the dashboard is a list of all the intermediate steps performed in the job.

In this work we present an image registration example with the NUMERICS platform using typical tomographic images from a stress/rest myocardial perfusion SPECT study. The SPECT images are taken from [3]. The image registration algorithm for this case is configured to use Möbius transformations. The optimization algorithm is set to the Levenberg-Marquardt Algorithm. The cost function used is Sum of Squared Differences.

**Results**

A screenshot of the dashboard showing the obtained results from the submitted stress/rest image registration job is shown in Fig. 3. In the center of the dashboard the rest image is shown after it is registered to the stress image. A histogram of the distribution of pixel intensities in the image is shown in the bottom part of the dashboard. On the right side of the dashboard, in the "Misc. Statistics" section, the user can find information about the best parameters of the Möbius transformation that were found by the optimization algorithm. In

this case the parameters for the geometry transformation are the translation coordinates and the rotation angles of the projection sphere that is used to perform the Möbius transformation [1]. At the bottom of the section are shown the values of the available cost functions. Figure 4 shows an overview of the described registration job. The figure contains the originally submitted stress/rest images, the registered rest image and the difference images before and after the registration. These images allow the user to check visually the results from the registration. For example, we see that the big differences in the initial difference image (Fig. 4c) are largely reduced after the registration (Fig. 4e). In addition, quantitative information about the registration results can be extracted from the difference image statistics, available on the dashboard (see. Fig. 3). Finally, it is evident that a perfect image registration algorithm will match the two images and will reduce as much as possible the (statistically significant) differences between them. Therefore the statistics on the detected differences after the registration, which are also available on the dashboard, can be used as a standalone tool for evaluation of the performance of the NUMERICS image registration algorithms and can as well be used to evaluate the performance of other, third-party image registration algorithms.

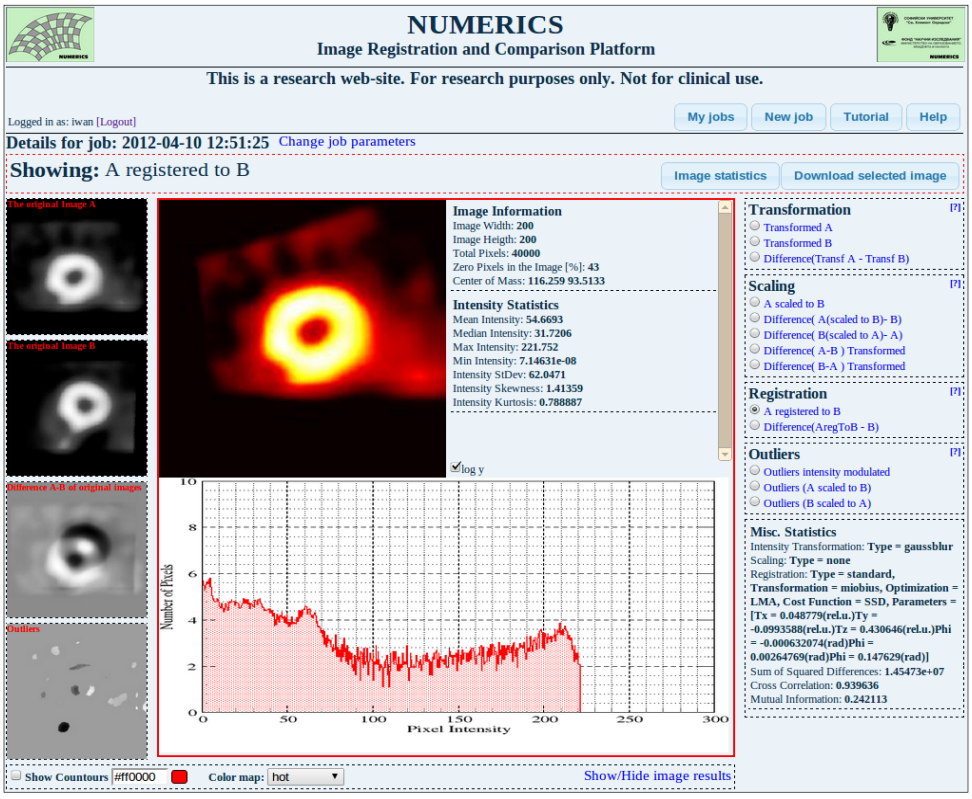


Figure 3. Results from the stress/rest image registration job. The figure shows the obtained statistical information about the registered rest image and the used geometry transformation.

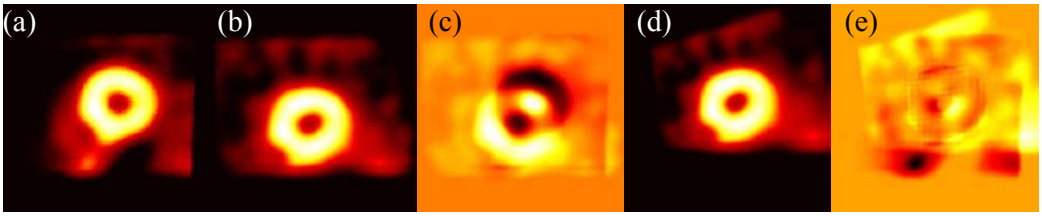


Figure 4. An overview of the job presented in this work. (a) and (b) - the original stress/rest images. (c) - the difference image of the original images. (d) - the rest image registered to the stress image. (e) - the difference image after the registration.

**Conclusion**

The NUMERICS image registration and image comparison platform is a useful tool that provides the user with accessibility to a variety of image registration and image comparison algorithms. The platform provides detailed statistical information about submitted image registration jobs and can be used to perform quantitative evaluation of the performance of different image registration techniques. Therefore, the platform can be used by medical physicists developing and using numerical image processing algorithms.

**Acknowledgments**

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**References**

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