1.2 Algorithm - Noise reduction on the image

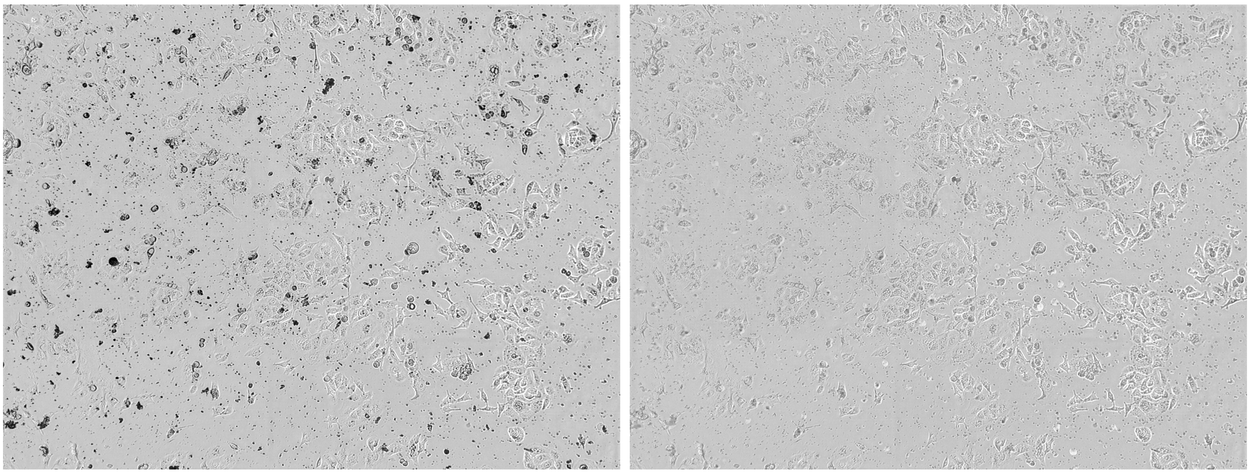
1.2.1 Abstract

In many branches of the biochemical industry, experiments are conducted on cells, where they are exposed to various substances which may affect their behavior. Many times these substances are visible in the result of the experiment, especially often they might appear on the image from a optic microscope, making manual analysis less clear and altering results of a automated image analysis. To compensate that problem, flexible algorithm based on the MIC technique and connected-components was developed and described in this article. This algorithm can successfully delete the noise on the image, based on the difference in brightness and size, and is applicable to the optic microscope images.

1.2.2 Summary

The topic of noise reduction is well known in the field of data science and image analysis. It had its peak in early 90's, when the quality of the images was poor and often required correction, but nowadays as the technology advanced, it is present more in a laboratory or experimental work, where achieving the highest precision often results in less quality of the results. In the field of studying the biological images, the noise is often not the result of the technology, but of the pollution or unwanted substances in studied samples [figure 12]. This type of noise differs substantially from what was widely known for years in the field of image analysis. Because of that, many techniques, including the popular Gaussian Blur or Fuzzy filtering [1], are incapable of deleting the noise, mainly because they are incapable of qualifying bigger objects on the image as noise. This conclusion leads us to the usage of the mathematical morphology to handle the qualification problem better. Morphology operations are capable of detecting the components with similar characteristics using the tools like connected components [2] and deleting them using dilation or erosion. Morphology approach to the noise reduction problem was already implemented in various studies [3-4], but the algorithms proposed there are reducing the details significantly, and in some cases they create new structures on the image [4]. In this work, proposed is the algorithm which is capable of reducing the noise on the image from a optical microscope with preservation of the structures and shapes of the objects. The algorithm

is based on the basic morphological operations, and can be configured to have stronger or lighter influence on the image. The algorithm was fine-tuned on various images and the best force value was evaluated, resulting in the highest noise reduction with the lowest lose of the details.



(a) Example of the image from the optical microscope, visible are the unwanted black structures (b) The same image after reducing the unwanted structures, which are the noise

Figura 8: Images showing the noise from the optical microscopic images

1.3 Algorithm breakdown

1.3.1 Labeling the potential areas with noise

The algorithm uses the mean value of brightness on the image to detect the potential noise, which the algorithm distinguishes to the 2 groups: objects which are darker than the mean, and objects which are brighter than the mean. In the default mode, the algorithm chooses the darker objects as noise, but it can be modified to choose the brighter ones. After that, the algorithm uses the connected components to label all the regions which are qualified as noise. After that, the size condition is verified, and all the regions which are larger than the specified size are omitted in any further actions, and left on the image.

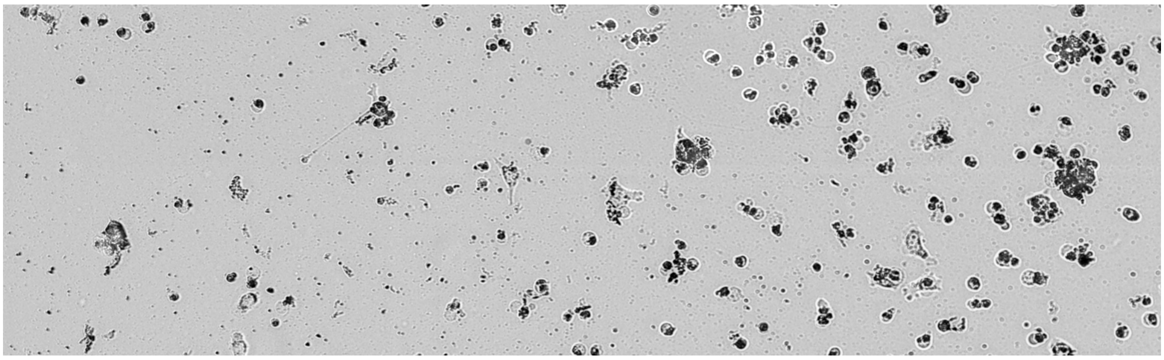
1.3.2 Deletion of the noise

The labeled regions are then iterated, with each being submitted to the following operations:

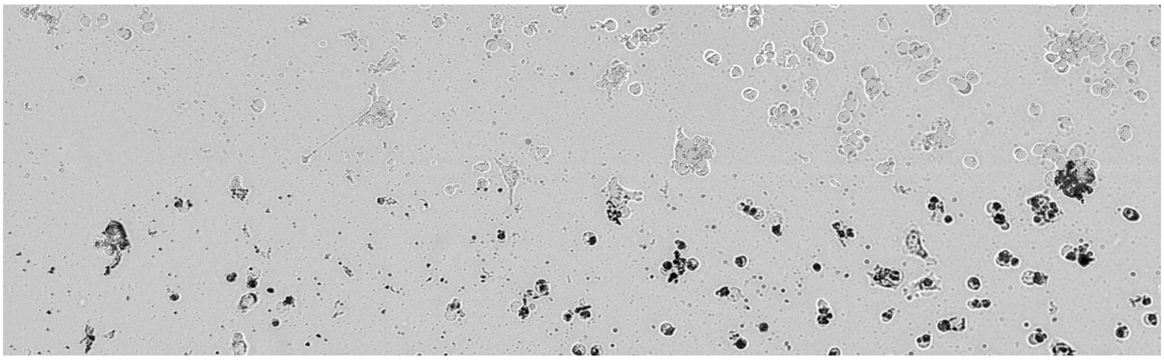
- **Dilation of the area:** In this step the initial mark of a single labeled area is broaden, resulting in the bigger area of action for the further steps. Note that this step does not alter any pixels on the image, as it only broadens the marker of the region, which is stored in a different variables. [Figure 13 b]

- **Paint over and second dilation:** In the second step, the area is repainted to the color of the brightness of the image. After that, the second dilation takes place, again only the area of the mark is altered by dilation, the image does not undergo any dilation. [Figure 13 b]
- **inpaint process:** The last step is the inpaint of the image. Inpaint is the morphological technique to blend the background of the object with it's foreground. This step is not obligatory, as for the images with small resolution, it can paint the area with the wrong color. [Figure 13 c]

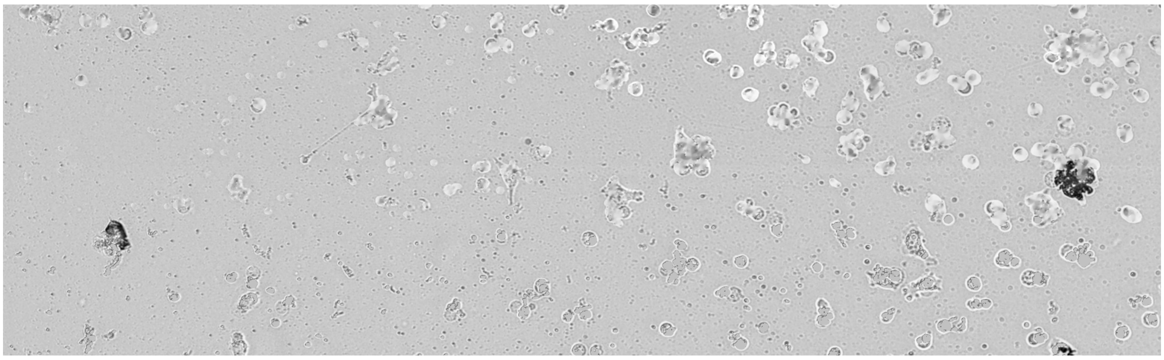
As visible on Figure a-c, In many cases the description of the noise as black objects on the image is hugely inaccurate, and the algorithm cannot just qualify the black regions of the image as noise. Due to that, the algorithm required adaptation to handle a variety of cases.



(a) Original Image



(b) Half of the image was altered by the initial dilation and paint over



(c) Half of the image was altered with the inpaint. In this example usage of inpaint is an incorrect decision.

Figura 9: Steps of the algorithm in example of the image with incorrectly qualified noise

1.3.3 The adaptation to diverse case studies

To prepare the algorithm to work in various type of biological studies, several variables, which influent the output of the image were distinguished, and the algorithm was rewritten to handle a variety of cases.

- **Threshold based on the mean brightness**: The threshold, from which the objects were qualified as the noise was set to be calculated based on the mean of brightness on the image. This approach ensured correct qualification of the structures.

- **Limit on the size of the marked area**: The limit to the size of the marked area was set to preserve objects with significant size.

- **Iterations**: The algorithm can be iterated with diversity of the values of the variables.

The algorithm also allows to change the size of the dilation and the size of the inpaint, as for the images with bigger resolutions, the amount of pixels building the same object is different.

1.4 Results:

Output of the algorithm vary significantly with the changes of the variables(arguments), with which it is processed. If used correctly, the deletion of the noise is flawless, although the diversity of the objects can still be visible. The algorithm lacks a mechanism for effectively removing all the signs of the noise from the image, thereby failing to ensure that the presence of the noise remains imperceptible to observers. The results of the test cases are shown on the figure 14-17. In all cases the original image was successfully reduced of noise. In case with higher inpaint values shown on the figure 16, visible is significant loss of the details. On figure 16 we can see the most promising results obtained after two iterations of the algorithm. The result could be even amplified with fine tuning and finding the most efficient number of iterations and variable values.

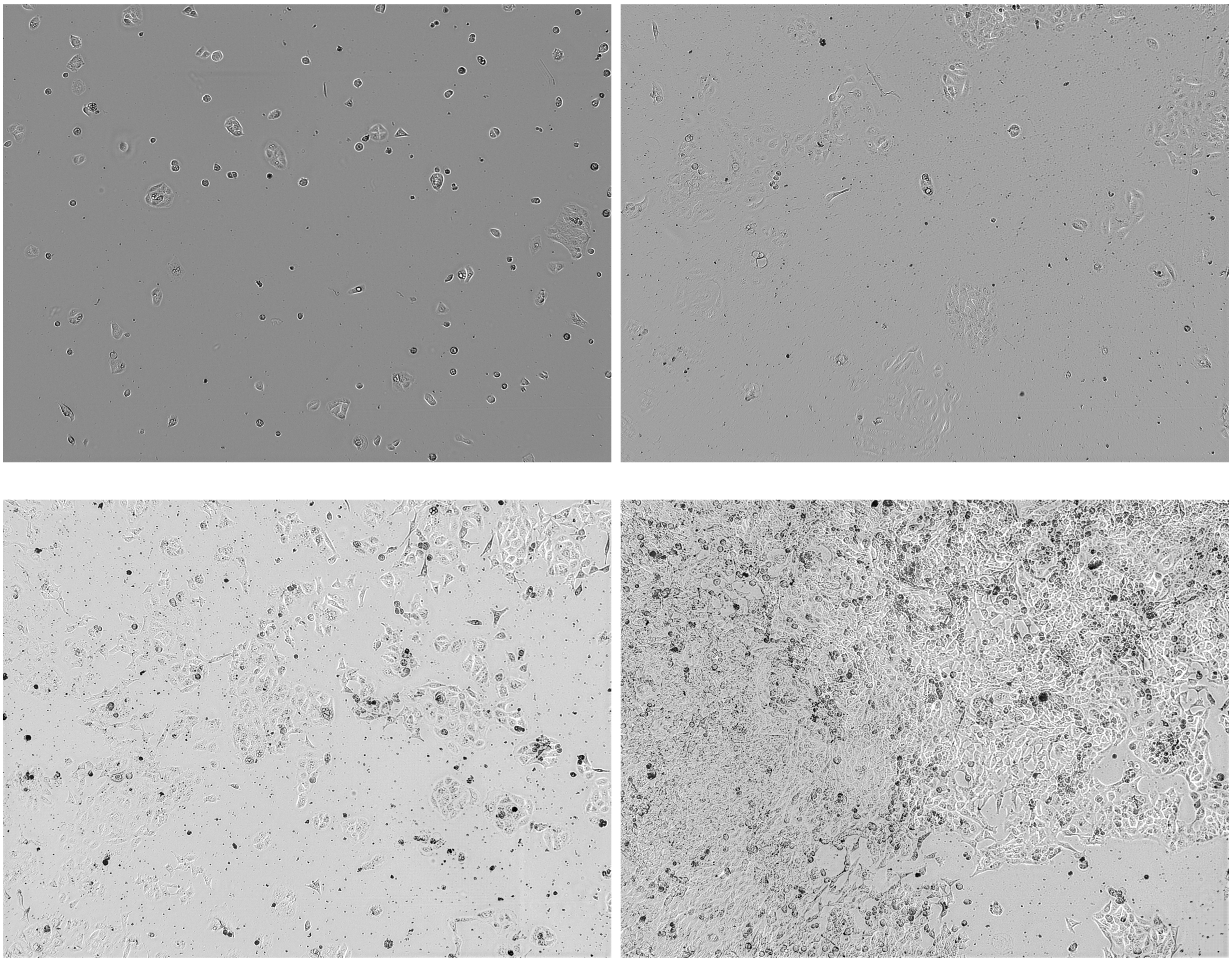


Figura 10: The images on which the algorithm were tested

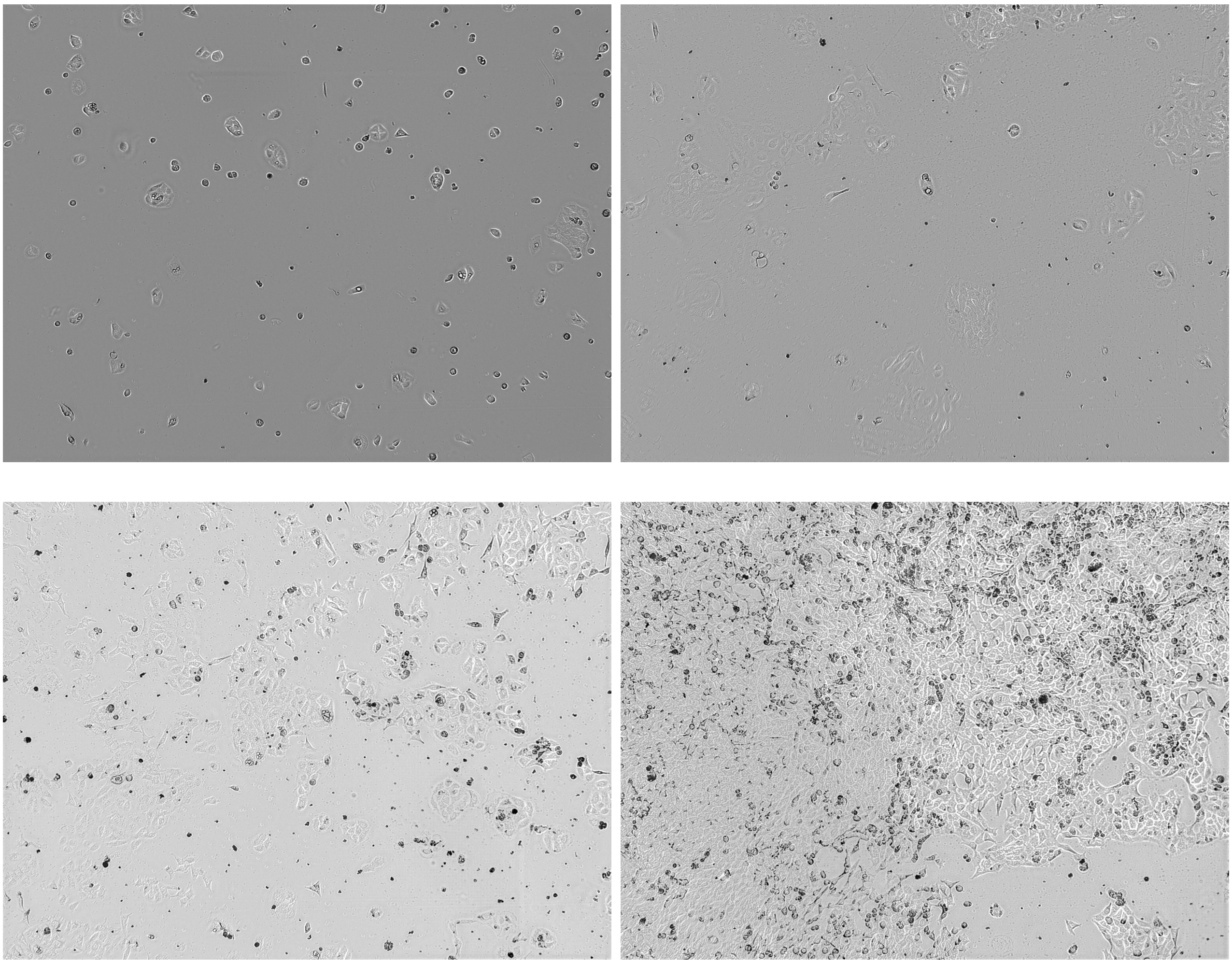


Figura 11: The result of running on the variables: threshold=2/3*mean, max marked size=30px, dilation=1px, second dilation=none inpaint=none

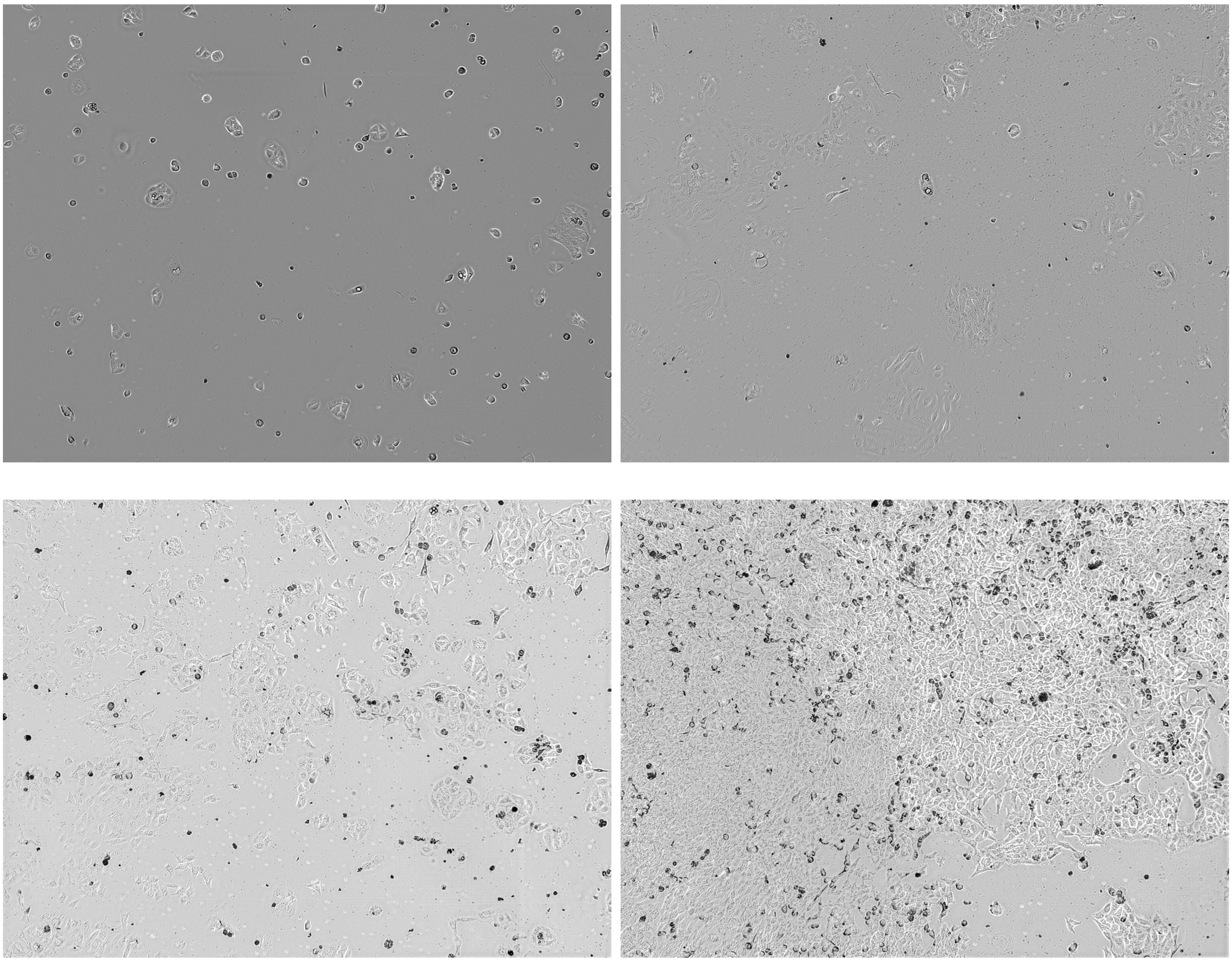


Figura 12: The result of running on the variables: threshold=2/3*mean, max marked size=30px, dilation=1px, second dilation=3px inpaint=3px

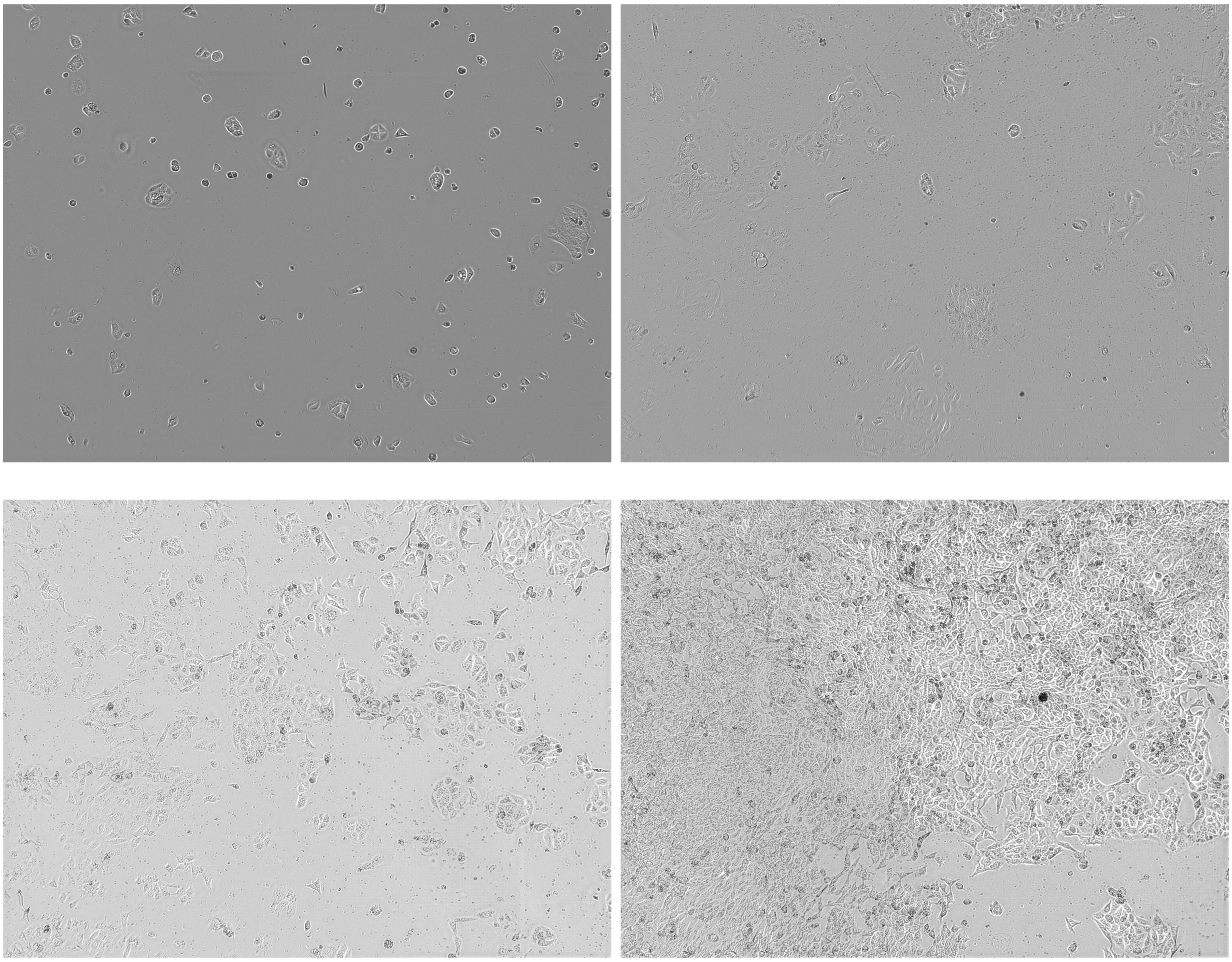


Figura 13: The result of running 2 iterations. first one with threshold=1/2 mean, max area size=30px dilation=1px second dilation and inpaint =none, second one with threshold = 8/25 mean, max area size=400, dilation=2px second filation and inpaint = none

1.4.1 Bibliografia

- D. Van De Ville, M. Nachtegael, D. Van der Weken, E. E. Kerre, W. Philips and I. Lemahieu, "Noise reduction by fuzzy image filtering,"in IEEE Transactions on Fuzzy Systems, vol. 11, no. 4, pp. 429-436, Aug. 2003, doi: 10.1109/TFUZZ.2003.814830
- openCV documentation, connected components `https://docs.opencv.org/3.4/d3/dc0/group__imgproc__shape.html#gaedef8c7340499ca391d459122e51bef5`
- R. A. Peters, "A new algorithm for image noise reduction using mathematical morphology,"in IEEE Transactions on Image Processing, vol. 4, no. 5, pp. 554-568, May 1995, doi: 10.1109/83.382491.
- Richard Alan Peters, "A New Algorithm for Image Noise Reduction Using Mathematical Morpho-