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Image analysis using Clemex Studio's artificial intelligence

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1. Introduction

Recent advances in artificial intelligence have given the possibility for image analysis to be simplified. One specific area of image analysis where artificial intelligence performs particularly well is called image segmentation. Image segmentation is the process of partitioning an image into classes. An example of this is segmentation of a delta-ferrite alloy metallograph into its primary and delta-ferrite phase as shown below in Figure 1.

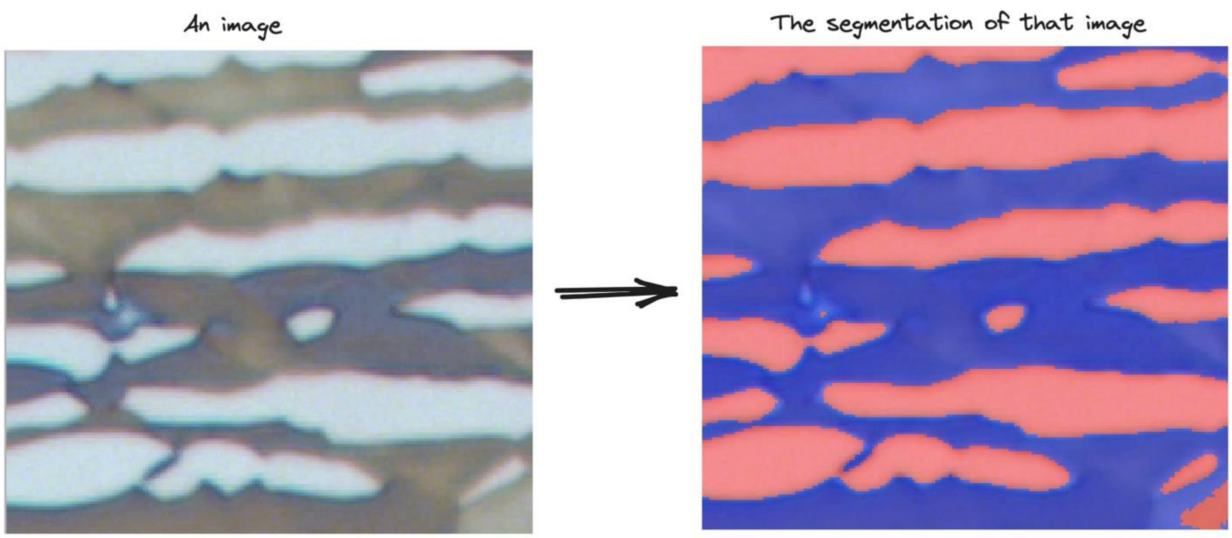


Figure 1 : Segmentation of a delta-ferrite alloy micrograph

Image segmentation is usually the most complex part of image analysis. Most microscopy image analysis softwares have historically relied on thresholding and then image morphology techniques for achieving such a result. Metallographers are typically trained at using such tools but quickly forget how to use thresholds and complex morphological operations necessary to extract salient features and perform automated measurements.

In practice, we also find that even the most experienced user of threshold and image morphology tools cannot get to the segmentation accuracy that artificial intelligence techniques can yield.

In this paper, through the presentation of two use cases, we argue for the replacement of traditional techniques with machine learning approached with two possible benefits.

1. The first one is to reduce the cognitive load of operators of microscopy equipment by making it easier to develop automated microscopy workflows.
2. The second one is to allow for automation of workflows that cannot be automated with traditional techniques.

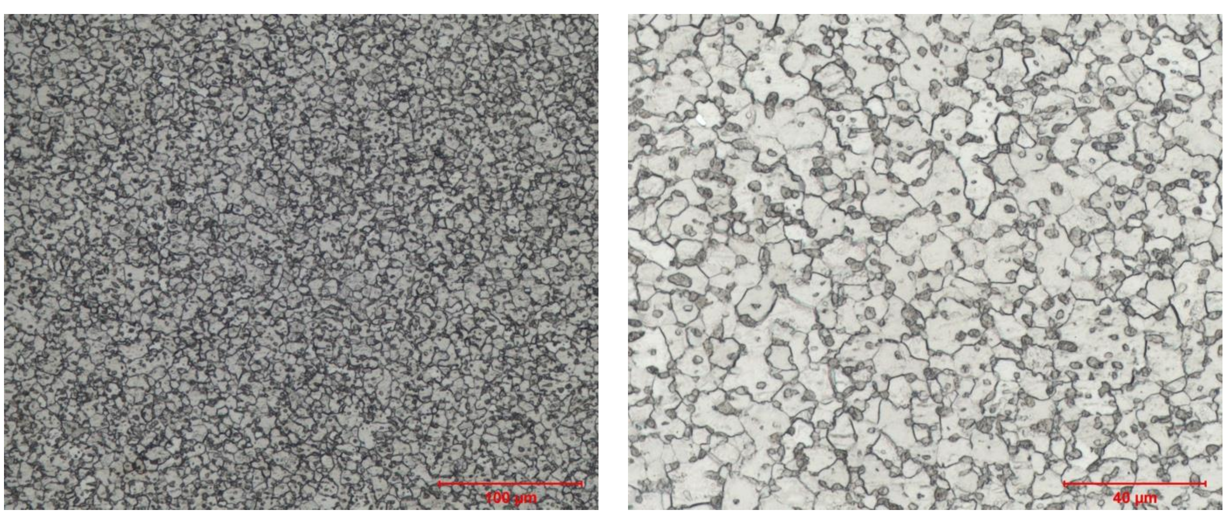
2. Case Study – Characterization of Ti64 wire

The first case study we want to approach in this paper is related to the microstructural characterization of Ti64 wire, an alloy containing 6% weight of aluminum (Al) and 4% weight of vanadium (V). Titanium has two dominant allotropic phases, alpha and beta phases. Beta phase is body centered cubic (BCC) and the alpha phase is close-packed hexagonal (HCP). Alpha and beta phases, and their orientation, is responsible for the difference in properties between titanium's alloys. It is, therefore, of great importance to understand how alpha and beta phases can modify properties for the better or worse. A key element in understanding how the microstructure changes with deformation processes and heat treatments is to characterize the morphology and the ratio of the two phases through image analysis.

Traditional image analysis is sometimes unable to answer microstructural questions. If it is, methods or algorithm development is most of the time inneficient and requires competencies that a typical metallurgist does not have. However, as new technologies immerge, new ways to analyze images are also becoming available to the industry. One hot topic is the use of Artificial Intelligence (AI) to help solve problems that would otherwise be a harsh task to tackle.

In this study case, the use of traditional image analysis could not provide accurate results. Because of that, Clemex Studio's AI was used to characterize the microstructure of a Ti64 wire sample. The main objective was to retrieve information regarding morphology of the beta phase. More specifically, the following features were analyzed: aspect ratio, length, width, area, perimeter, feret 0°, feret 90° and percentage area.

To do so, it is first necessary to find a suitable etching protocol for discriminating between beta and alpha phases. It was found that a mix of sodium hydroxyde (NaOH) with hydrogen peroxide (H_2O_2) did reveal sufficient contrast between alpha and beta phases. Here is an example of the result obtained after etching, at 200X and 500X magnification (Figure 2).



A) B)

Figure 2 : Ti64 wire metallographies – A) at 200X with NaOh + H_2O_2 and B) at 500X with NaOh + H_2O_2

From Figure 2, we can see beta phase particles (grey), located mainly at grain boundaries, in an alpha phase matrix (white). Because of multiple structures have similar gray levels, using traditional image analysis tools to analyze this microstructure would be difficult at best and unlikely impossible.

By using Clemex Studio to discriminate beta phase from alpha phase matrix it was possible to teach and train the AI to recognize the beta phase. Figure 3 shows a beta phase element as detected by an AI algorithm trained with Clemex Studio. It was necessary to add post processing steps to using Clemex Vision to refine segmentation of the beta phase. Though segmentation of alpha and beta phase was not perfect, it was largely sufficient to accurately segment the image.

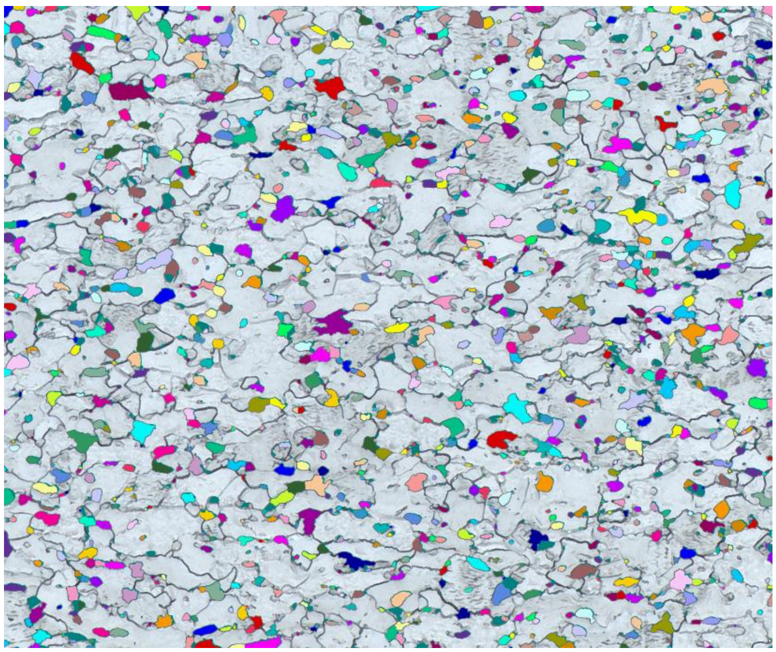


Figure 3 : Segmentation using Clemex Studio of a Ti64 wire

Also, we found that this tool made it possible to better segment a variety of images with incomplete grain boundaries and different grain shapes adding robustness to our process. As such, we could process a large quantity of images with a single method without having to do manual measurements or parameter adjustments from one image to another.

Clemex Studio outputs plugins that can be used in Clemex Vision's routine system. We added the TI64 phase segmentation plugin to a Clemex Vision routine which allowed us to collect quantitative data on microstructure (aspect ratio, length, area percent, etc.).

For comparison, we did try to develop an image analysis method using threshold and other traditional computer vision approaches without success, mainly because of streaks and different hues in the alpha-phase titanium grains.

3. Case study – Sludge contamination in diecasting aluminum alloy A380

The second case study deals with a contamination problem in a die casting aluminum alloy A380. The contamination problem was first discovered by chemical composition analysis of the melt throughout several days. Unexpectedly, iron content in the aluminum alloy A380 was out of specifications. Usually, chemical composition problems come from an error in adding alloying elements. However, in this case, A380 ingots were melted, and the mill test certificate did not show any sign of problems from a chemical composition point of view. After discarding the hypothesis that the spectrometer might not be calibrated correctly by testing samples in different laboratories and obtaining similar results, a further analysis was done by looking at the microstructure.

Samples with different iron concentrations were chosen for this microstructure analysis. They were cross-sectioned, mounted and polished to reveal the phases. No etchant was used in this project. Here is an example of the microstructure observed (Figure 4)

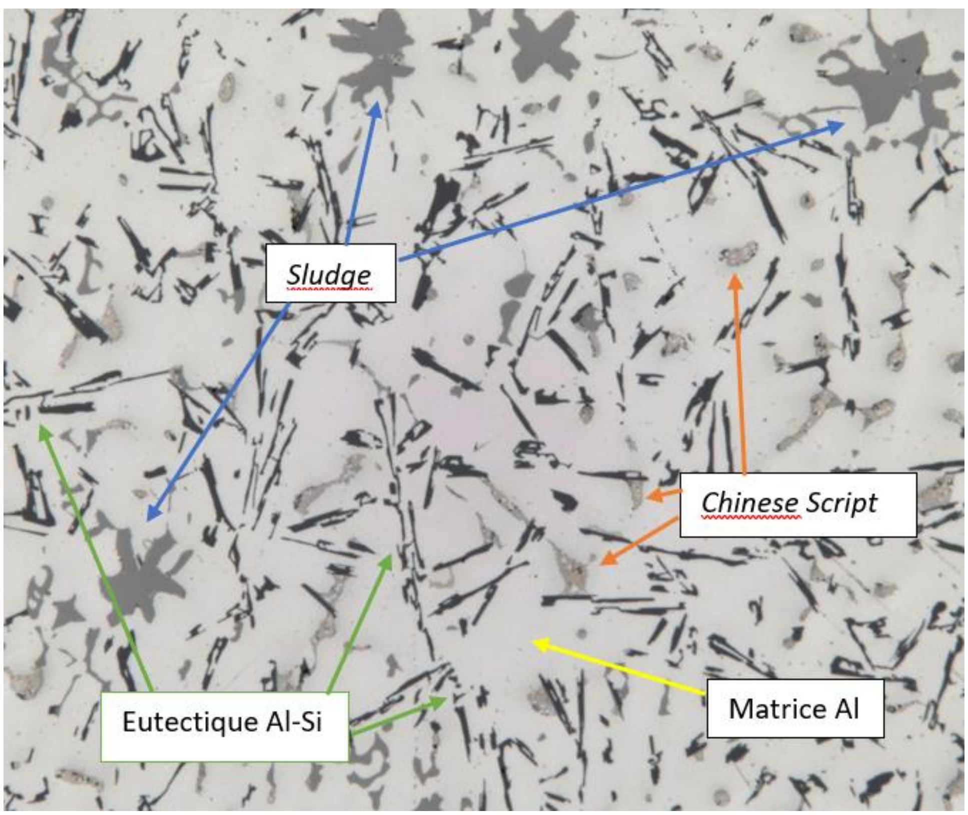


Figure 4 : Identification of different phases in aluminum A380

As illustrated by Figure 4, the microstructure is composed of a eutectic phase Al-Si, copper-rich *chinese scripts* and sludge particles in an aluminum matrix. Al-Si eutectic is represented by dark plate-like particles and *chinese scripts* are represented by a light grey phase. Sludge particles represented by grey large island-like with irregular morphology. Those particles are not desired in an aluminium alloy A380 and are usually formed from a high concentration of manganese, chromium and iron or melting parameters. Since chemical composition is out of specification because of a higher content in iron than expected, sludge particles were the main concern from that point forward.

Using Clemex Studio's AI, the segmentation was done by teaching and training the AI to recognize the sludge particles only, since Al-Si eutectic and *chinese scripts* are not detrimental to the alloy mechanical properties and are not the source of iron contamination. However, sludge particles might be a consequence of the higher iron content in the alloy. To further investigate that hypothesis, multiple fields were segmented to discriminate sludge particles for each A380 sample selected. The main purpose for that was to retrieve data regarding area % covered by sludge particles and correlate with the chemical composition results.

Clemex Studio's AI was very helpful in segmenting the images, especially because the contrast in grey color between the Al-Si eutectic, the *chinese scripts* and the sludge particles are relatively close to one another. So basically, thresholding can be difficult using traditional techniques. Also, since the morphology of the sludge particles differs largely from the Al-Si eutectic and *chinese scripts*, Clemex Studio's AI was able to easily recognize the sludge particles and isolate them. Figure 5 shows a segmentation done by Clemex Studio.

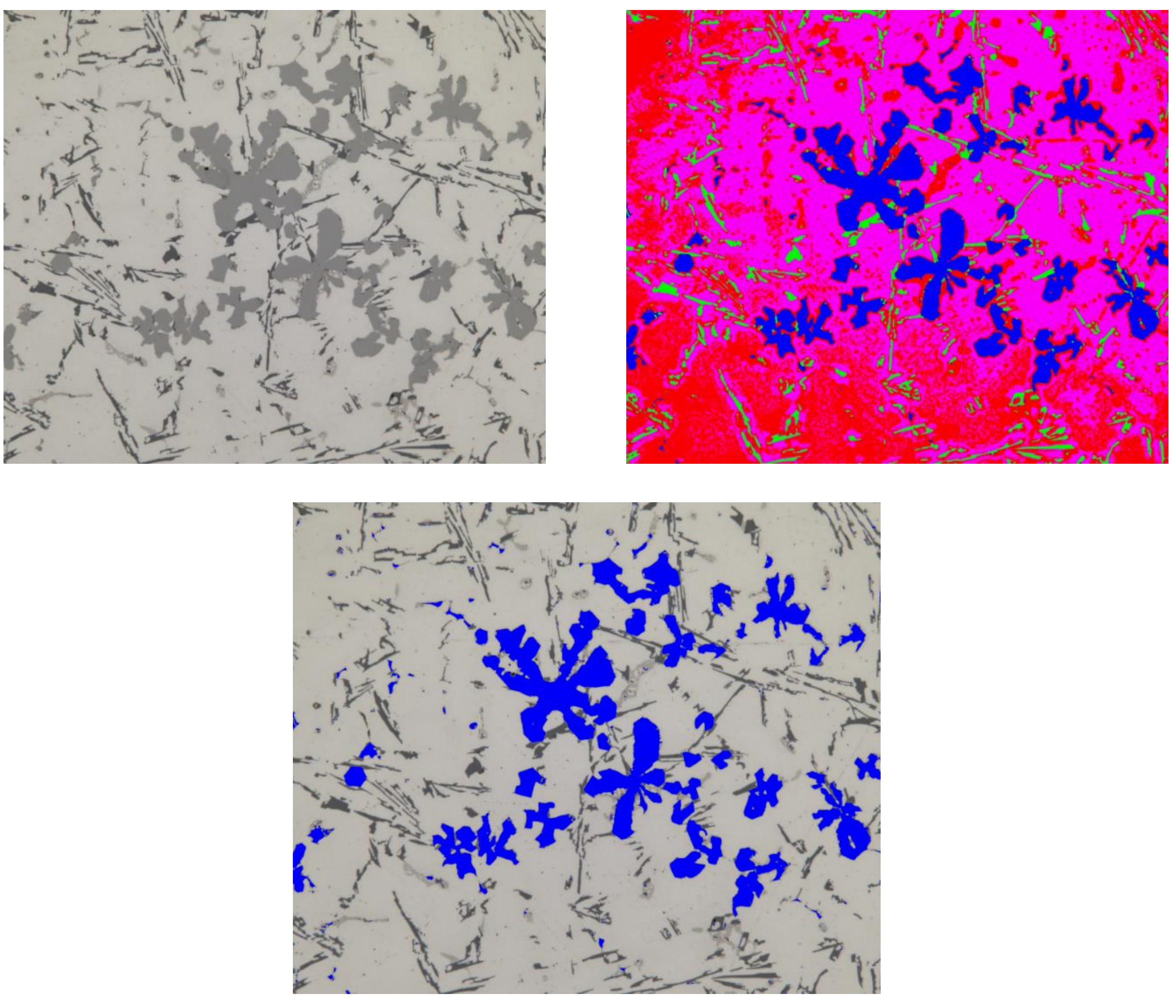


Figure 5 : Segmentation of aluminum alloy A380 contaminated with sludge particles

Once the segmentation is done by Clemex Studio, a plugin is generated and can be used in Clemex Vision's routine to provide the information needed. In this specific study case, we were interested in knowing the area percentage covered by sludge particles in multiple images and correlate the results with the chemical composition analysis.

This study case is a good example of a project in which Clemex Studio's AI was able to reduce cognitive load of operators of microscopic equipment by making it easier to develop automated microscopy workflows. Indeed, from user's feedback, it is clear that the use of Clemex's AI technology can be translated into a gain of time. The learning process of the AI was quite fast and required a small number of images to be fully functional.

4. Conclusion

The main purpose of this paper was to provide concrete examples of the benefits of using AI technology in image analysis for metallurgical needs. One of the benefits that can be associated with Clemex Studio is that a user without deep knowledge of AI technology or coding can easily use this tool. However, the user must have knowledge in the science field they work in. The case studies presented in this paper also agrees with the previous statement. Indeed, a metallurgy technician is able to recognize the different phases and constituents of a microstructure and use Clemex Studio for segmentation without knowing exactly how the AI is programmed. Since the segmentation is then provided in a plugin format, there is less effort put on the segmentation coding in traditional techniques.

Furthermore, two benefits were especially important to justify the use of Clemex Studio's Ai technology. The first benefit was to reduce the cognitive load of operators of microscopy equipment by making it easier to develop automated microscopy workflows. This was proven true in the sludge contamination study case where the use of Clemex Studio was time saving and the learning process of the AI was fast and accurate using a small number of images. The second benefit was to allow for automation of workflows that cannot be automated with traditional techniques. This was proven true in the Ti64 wire characterization study case where the routine needed to the segmentation in Clemex Vision would have been awfully difficult to create without a deep knowledge of coding.

In conclusion, Clemex Studio have proven is usefulness through the two study cases presented in this paper. We believe that this tool can help save time and reduce cognitive load of operators in many different scenarios.

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Project manager name, title.

Continuous Improvement Process

We strongly hope that we fulfilled all your needs and answered all your questions. From there, in our continuous improvement process ISO 9001 : 2015, we need to receive your comments in a way to improve our metallurgical interventions and assistance. Thank you for participating in our continuous improvement process.