Instance segmentation of mineral grains in thin section images

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Introduction

The paper considers developing the algorithm for instance segmentation of mineral grains in thin section images of sandstone. This task involves the segmentation of objects of a quasi-convex shape without occlusions. Most often grains are tightly packed. In the process of lithogenesis, most of the grains have strongly been transformed, as a result, the localization of some grains and their boundaries can be extremely difficult.

The considered task is the key to constructing a numerical description of rocks for the mining industry and engineering geology. According to the results of segmentation, the granulometric characteristics, shape and packaging parameters can be calculated for the studied sandstone samples.

Workflow

To build a solution based on expert interpretation, we have accumulated a dataset of more than 9,000 individual mineral grains (45 images). We factorized the original problem and sorted the subtasks according to expert evaluation from simple to complex:

- Proposals localization;
- Grains edges localization;
- Proposals filtering.

For localization of proposals, we use a CNN model, restoring the normalized distance transform of individual grains \( \Omega \) from the original sample images:

\[
|\Phi(\mathbf{r})| = \frac{1}{\max(\Phi(\mathbf{r}))}, \quad \text{if } \mathbf{r} \in \Omega.
\]

Transform \( \Phi(\mathbf{r}) \) is invariant for objects shifts and can be approximated using convolutions. To avoid proposals filtering task in this step the error functional (\( L_1 \) distance) was optimized only in the areas occupied by grains. In the remaining areas of the image, the model was given freedom of choice.

Results

Case 1: small grains

Case 1: large grains

Complicated cases

The segmentation runs correctly both in case of simple objects (such as clean quartz) and in complicated cases (such as polysynthetic twinning, extinction, relict grains, secondary modifications, quartz regeneration). This quality of model prediction was verified on validation sample (10-fold) and on testing sample using error correction result. This procedure allowed us to accumulate a sample of 300 images (over \( 10^5 \) grains).