

A GIS-based Evaluation of Grain Roundness

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Background and Objectives

In sedimentary studies one of the physical properties of the examined samples is grain roundness; a critical parameter providing information about the depositional environment and the physical processes that the material has undergone since its deposition. This paper describes an attempt to provide an automatic and accurate method to measure roundness of clastic particles from sediments. The technique, developed at the Marine Geology laboratory of HSGME, is based on the Wadell (1935) methodology, traditionally applied through laborious microscopic examination. To provide an automatic and out of the box routine Model Building tools and script development using Python Libraries in an ArcMap environment were involved. GIS was chosen as a practical solution for data elaboration and mapping both in marine and terrestrial sedimentary studies.

Methodology

According to Wadell (1935) the average roundness of a grain is calculated using the formula: $Roundness = (\sum r_i/n)/R_{max}$, where r_i is the radius of curvature of every angle of the grain, n is the number of angles and R_{max} is the maximum inscribed to grain circle (Fig. 1a). Taking that into account, the toolbox design in ArcGIS involved the following concepts:

- Use of simple equations of differential geometry for the calculation of radius of curvature (r_i).
- A set of three vertices is used at each calculation step to define a triangle and a circumscribed circle (Fig 1b).
- The radius of the circumscribed circle corresponds to the radius of curvature at the part of the grain boundary curve defined by the three active vertices.
- Successive sets of three (3) vertices are used for every calculation step.

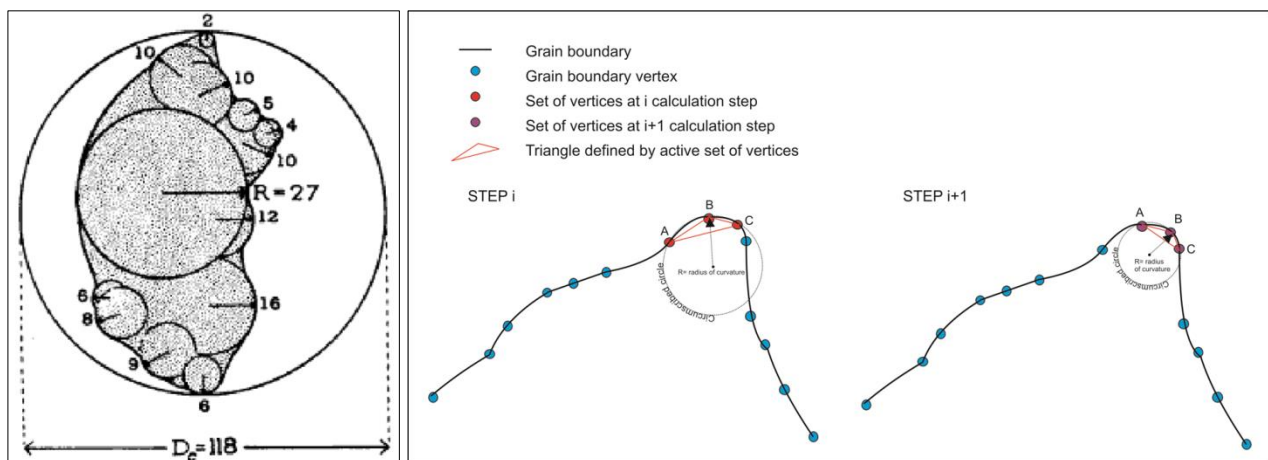


Figure 1. The basic concept of the Wadell (1935) methodology (left) and its application through the ArcGIS toolbox (right).

For the practical application of the above methodology a high resolution image – captured during optical microscopy examination – of the studied sample is required. To ease the processing, before import in ArcGIS the raster undergoes image analysis, using Python scripting, by application of Gaussian filtering and the Otsu (1979) thresholding method, to “extract” the grain boundaries in the form of a black and white binary image. Possible restriction may, however, arise in cases of polymictic grains, exhibiting a variety of colours which may complicate image processing.

The calculation of specimen roundness in ArcGIS, from its microscopic image, is accomplished using an in-house custom-made Toolbox (“Roundness.tbx”), using the following tools: spatial analyst, conversion, editing, geoprocessing by model builder and Python calculations.

To test the applicability, validity and accuracy of the aforementioned methodology the roundness of the published prototype grains by Wadell (1935) was calculated (Fig. 2) and compared to that, measured manually, quoted in the publication. Additionally, a set of 20 individual grains was used, with nominal roundness ranging from 0.1 to 0.9 and the mean deviation from Wadell values was 0.02 (Fig. 2).

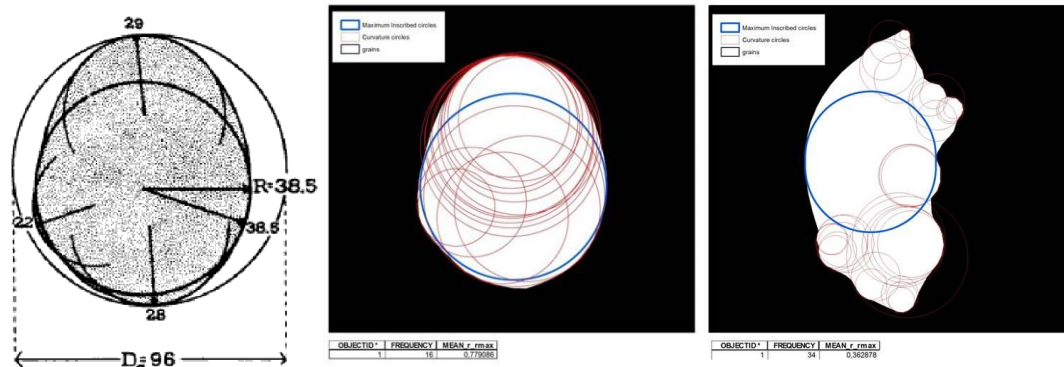


Figure 2. Validation using Waddell (1935) “grains” for a round (Waddell $R=0.81$, Model $R=0.78$) and an angular (Waddell $R=0.30$, Model $R=0.36$) grain.

Conclusions

The proposed methodology can accurately calculate the roundness of sediment samples, irrespective of their nature and environment. It is fast, cost-effective, totally automatic and thus free from user bias and random errors. The created toolbox is user-friendly and its application in a GIS environment – broadly adopted in data processing in earth science worldwide - does not involve any other special software.

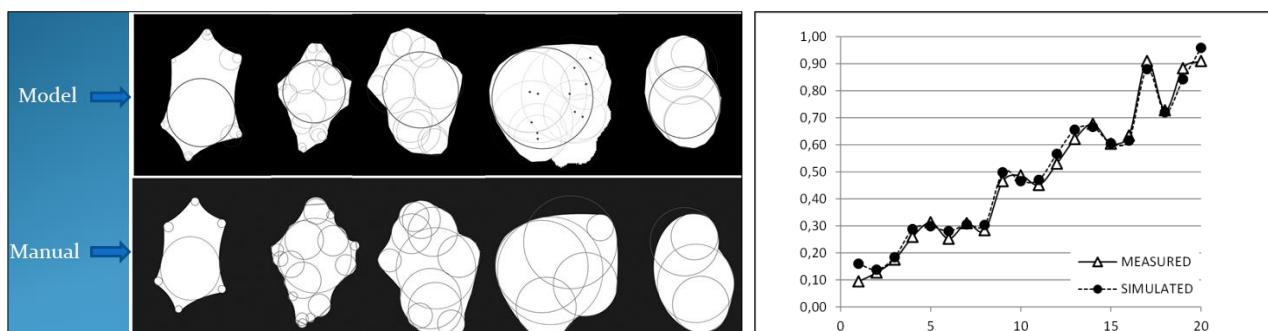


Figure 3. Model validation using a set of 20 grains of optimum roundness; manual data from Waddell (1935).

This novel approach, using GIS not only for geospatial data management and representation, but also for the generation of original data can be taken one step further. Future work will focus on using the tool for batch image processing images and embedding the *Roundness* Toolbox into an integrated tool for storing and mapping the results. Thus, for a set of samples from a region, after roundness calculation, the resulting data will be correlated with the required geospatial information (sample coordinates) and the corresponding map will be drawn allowing a combined interpretation.

Acknowledgments

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References

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