Grain Size Analysis Using Machine Learning

Bachelor of Technology
In
Computer Science and Engineering

Submitted by

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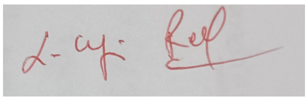
I hereby confirm that the research conducted for the project titled “Image processing and analysis for Grain size Characterisation a Comprehensive approach" was undertaken by Nayudu Ravindranath Chowdary, Poola Harish, Bogineni Krishna Satya Sai Ram, Kakarla Sashank Chowdary and Chidipothu Rushendra Sai under my supervision. I affirm that the content is authentic, original, and appropriate for submission to SRM University – AP, seeking the Bachelor of Technology / Master of Technology degree in the School of Engineering and Sciences.



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We wish to extend our deepest gratitude to all those who played a crucial role in bringing this research project complete. Firstly we would like to extend our appreciation to Dr. Gangi Reddy Salla sir , our esteemed supervisor/advisor. His guidance, encouragement, and invaluable insights have been pivotal throughout the research endeavour.

A sincere acknowledgment is due to the participants of this project, whose cooperation and openness in sharing their experiences and perspectives proved invaluable to the success of this work.

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Abstract

This work provides a complicated image processing and analysis approach for the categorisation of particles in microscope photographs. The recommended procedure combines editing, multi-stage processing, and photo file alteration to increase particle exposure. Particle segmentation and outline filtering procedures are employed to obtain significant features, and then a detailed analysis of particle sizes, locations, and aspect ratios is done. In addition to depicting the dispersion of particle sizes, a 3D scatter map includes information on the physical attributes of the particles. Gray Level Co-occurrence Matrix (GLCM) characteristics are employed in this study's unique texture analysis approach to offer a more detailed knowledge of particle composition. Additionally, the research assesses KMeans labelling using GLCM, which depicts distinct zones inside the image. Contour analysis is carried out on edge-detected photos, and ground characteristics are created for every site that is identified. The recommended technique gives a detailed framework for identifying particles, giving essential insights for usage in biology, material science, and environmental tracking.

Keywords— Image Processing; Particle Segmentation; Contour Analysis; Texture Analysis; GLCM Features; KMeans Clustering; Microscopy; Material Science; Environmental Monitoring.

Previous Models

The proposed method for classifying particles in microscope photographs represents a sophisticated approach to image processing and analysis. Unlike previous models, this technique uses a multifaceted process that includes editing to increase particle exposure, multi-step processing and photo file conversion. The multi-step process ensures a thorough investigation of particle properties and facilitates an understanding of particle composition and distribution. In this detailed analysis, the method focuses on particle segmentation, contour filtering, and subsequent examination of particle sizes, positions, and aspect ratios.

Previous designs and approaches:

1.Rosebrock (2015): The piece is inspired by Rosebrock (2015) and emphasizes the importance of changing image formats to improve the consistency of photographs for later research. This first step in the procedure emphasizes commitment to basic image preprocessing techniques.

2. Jones (2019): Jones (2019) provides an overview of image cropping techniques and emphasizes their role in reducing extraneous data and improving computer performance. This is consistent with the proposed method and the goal of improving particle exposure through multi-step processing.

3. Bradski (2000): The approach is based on Bradski et #039; (2000) for an overview of basic image processing techniques using the OpenCV library. Using OpenCV creates a solid foundation for later complex analysis.

4. Seah and Wang (1998): The texture analysis approach brings a unique element to the method based on the use of Seah and Wangand #039 (1998) of Gray Level Co-occurrence Matrices (GLCM) in texture. segmentation This departure from traditional methods increases the complexity and richness of the analysis.

5. Wickham (2016): The use of 3D scatter diagrams to illustrate particle size is consistent with the principles discussed in Wickham (2016). He emphasizes the characteristics of successful data presentation from traditional visualization methods. This incorporation of effective data visualization principles contributes to the method and theoretical framework.

6. Sciaini and Fritsch (2019), van der Walt et al. (2011): The use of contour analysis techniques is theoretically supported by Sciaini and Fritsch (2019) and van der Walt et al. (2011), which ensures consistency with contour-based analysis and object recognition.

Recommended Method and Unique Contributions: The recommended procedure combines these basic principles into a unified framework for particle detection. The multi-step process involves the use of image editing and transformation, particle segmentation and contour filtering techniques. These steps lead to a detailed analysis of particle sizes, positions, and aspect ratios, providing a comprehensive understanding of particle properties.

Texture analysis with GLCM:

A special feature of this method is the inclusion of GLCM features in the texture analysis. This unique approach provides more detailed information about particle composition, which improves the granularity of information extracted from microscope photographs.

Indicates labeling with GLCM:
The study estimates KMeans records using GLCM, which brings a new dimension to the analysis. This method helps to describe different zones in the image based on textural features, helping to understand the nuances of particle distribution.

Contour analysis and soil properties: Contour analysis of edge-detected photographs and generation of ground features for each detected object represent advanced stages of the proposed technique. This detailed analysis ensures a thorough investigation of the particle properties and further enriches the knowledge gained from the microscopy images.

Applications in various fields: The proposed technique provides a comprehensive framework for particle detection and provides significant insights for applications in biology, materials science, and environmental monitoring. Its advanced image processing and analysis method make it a valuable tool for researchers and professionals who want to deepen their understanding of particle properties.

In summary, the proposed method is based on basic models that include advanced techniques such as GLCM-based texture analysis and KMeans notation. This versatile approach improves the accuracy of information extracted from microscopic photographs and provides a sophisticated framework for particle identification in various scientific fields.

Statement of Contribution

		Contribution
• Bogineni Krishna Satya Sai Ram	–	Visualization and pixel size calculation
• Chidipothu Rushendra Sai	–	Image.j execution and report making
• Nayudu Ravindranath Chowdary.	–	Multi-stage processing and outline filtering
• Poola Harish.	–	Utilizing Gray Level Co-occurrence Matrix
• Kakarla Sashank Chowdary.	–	Integration of image preprocessing

Abbreviations

GLCM – Gray Level Co-occurrence Matrix

JPEG – Joint Photographic Experts Group

TIFF – Tag Image File Format

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Introduction

In various scientific domains, microscope photos have value because they give essential insights into the structure and composition of minute particles. The quick progressions in imaging technology have led to an excess of high-definition photos, necessitating creative approaches for image processing and analysis to permit efficient interpretation. We did this by establishing an enhanced approach for defining particles in microscope pictures utilizing image processing and analysis.

There are various formats for microscope photographs, each with its own particular set of characteristics. To make these photographs more helpful, the initial component of our process focuses on image format conversion and trimming. To offer a focused study area, precision cropping eliminates extraneous information, and converting from TIFF to JPEG format expedites additional processing steps. These exploratory initiatives provide the basis for a more focused and effective characterization method.

Our system's future components will require a multi-stage image processing pipeline. Photo enhancement methods, such as boosting contrast and brightness, are applied to improve particle visibility. In order to enhance particle boundaries and give more precise segmentation, sharpening kernels are applied sparingly. Subsequently, contour filtering and particle segmentation are done to uncover key characteristics, creating the scene for future investigation.

Because there are so many variable particle attributes, including as size, orientation, and aspect ratio, a multidisciplinary approach is necessary. We display the particle size distribution applying innovative technologies like three-dimensional scatter plots. Additionally, we present a new approach for texture analysis based on the features of the Gray Level Co-occurrence Matrix (GLCM). With this approach, we can more clearly detect even the slightest textural changes between particles, leading to a more exact understanding of their composition.

In the following sections, we present a detailed appraisal of the literature to situate our work in the larger picture of image processing and analysis. After that, we integrate theoretical principles with real code implementations to test our method. Our analysis of particle characteristics and their ramifications is summed up in the results and discussion section. The considerable results are reinforced in the last chapter, "Conclusion and Future Research," which also gives recommendations for future study.

Literature Survey

In the early stages of our system, we rely on cutting-edge picture preprocessing technology to lay the foundation for robust image analysis. Rosebrock (2015) underscores the importance of altering image formats as a crucial step in enhancing the consistency of photos for subsequent investigations. This alteration not only standardizes the images but also contributes to a more uniform and reliable dataset. Furthermore, Jones (2019) emphasizes the application of picture cropping techniques, highlighting their effectiveness in reducing extraneous information and, consequently, improving overall computer performance.

Moving into the realm of computer vision, the mainstream literature provides a rich tapestry of picture processing methods. Bradski's (2000) comprehensive overview introduces fundamental image processing techniques using the OpenCV library, a cornerstone of our approach. This library empowers our system with a robust set of tools for tasks like brightness and contrast modifications, forming the backbone of our image enhancement capabilities.

Delving deeper into the scientific literature, a significant body of work is dedicated to particle segmentation and contour analysis – critical aspects of our system. Seah and Wang (1998) offer a conceptual foundation for our texture analysis approach by introducing the use of Gray Level Co-occurrence Matrices in texture segmentation. This innovative technique enriches our understanding of particle composition by detecting subtle textural changes.

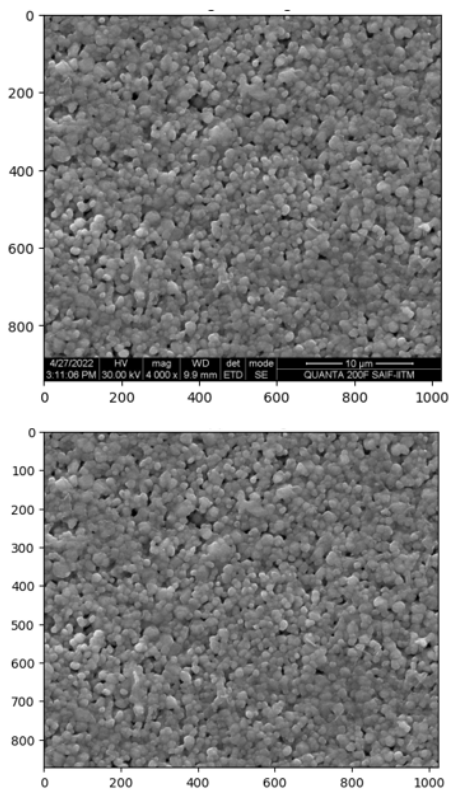
The concepts introduced by Sciaini and Fritsch (2019) and van der Walt et al. (2011) in morphological image processing and contour detection resonate with our contour-based analysis and object identification methods. These foundations enable our system to not only identify particles but also extract meaningful features, laying the groundwork for advanced analysis.

In the visualization realm, our approach aligns with traditional data visualization techniques. Using 3D scatter plots to illustrate particle size mirrors conventional practices. Wickham's (2016) insights on successful data presentation, particularly through ggplot2, guide our theoretical framework. This visualization method not only aids in understanding particle size distribution but also contributes to effective communication of our results.

In summary, our literature-inspired approach encompasses image preprocessing, computer vision techniques, particle segmentation, contour analysis, and data visualization. This comprehensive integration of methodologies from diverse literature sources establishes a solid foundation for our system's capability to analyze and interpret microscopic images, with applications in fields such as biology, material science, and environmental monitoring.

Methodology

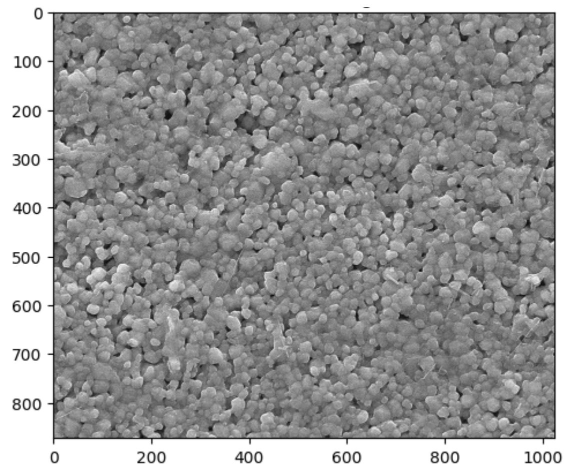
i.*Image Format Conversion and Cropping* :
According to Rosebrock (2015), the procedure starts with the conversion of TIFF microscope images to JPEG format. To standardize photographs and ease future processing, this step is important. Cropping algorithms are also used to reduce extraneous data in order to concentrate the query on the crucial area (Jones, 2019).



fig(1)

Image Format Conversion and Cropping

ii.*Image Processing Pipeline* :
There are approaches for improving particle visibility in the image processing pipeline. Standard computer vision algorithms are applied to induce oscillations in contrast and brightness (Bradski, 2000). Particle boundaries are indicated by sharpening kernels to facilitate segmentation.

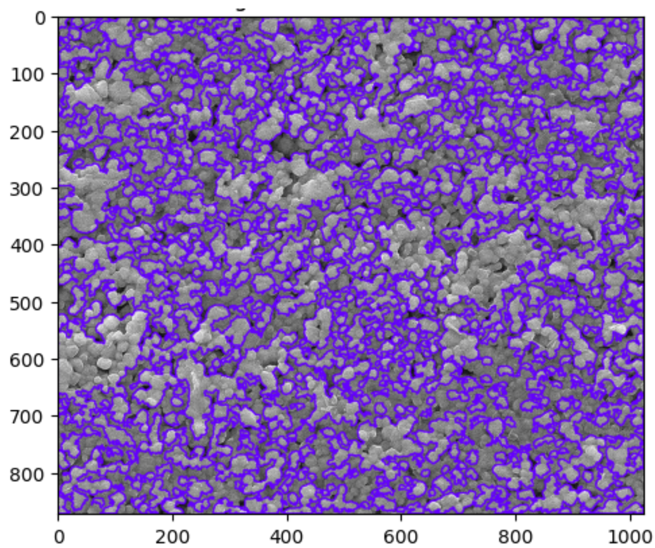


fig(2)

Image Processing Pipeline

iii.Sequential Particle Segmentation and Contour Filtering :

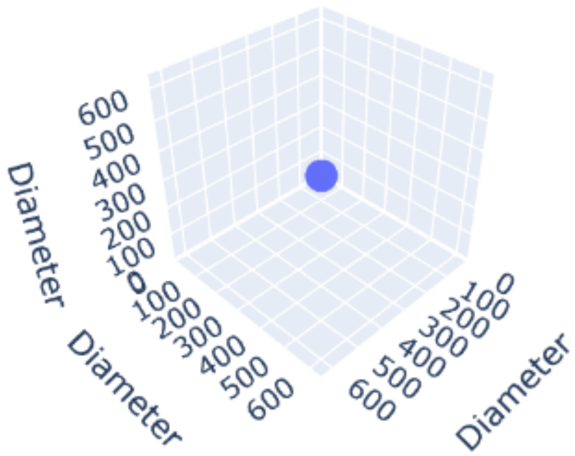
Sequential Particle Segmentation and Contour Filtering are morphological image processing algorithms developed by Sciaini and Fritsch (2019). While the filtering technique is based on contour area and eccentricity, the study on orientation and aspect ratio is based on the work of van der Walt et al. (2011) on contour detection and analysis.



fig(3)

Sequential Particle Segmentation and Contour Filtering

iv.3D Scatter Plot and Texture Analysis : The utilization of a 3D scatter plot to identify particle sizes is connected to Wickham's (2016) theories. The basis for the use of GLCM features for texture analysis was provided by Seah and Wang (1998), who proved the relevance of texture in particle characterization.

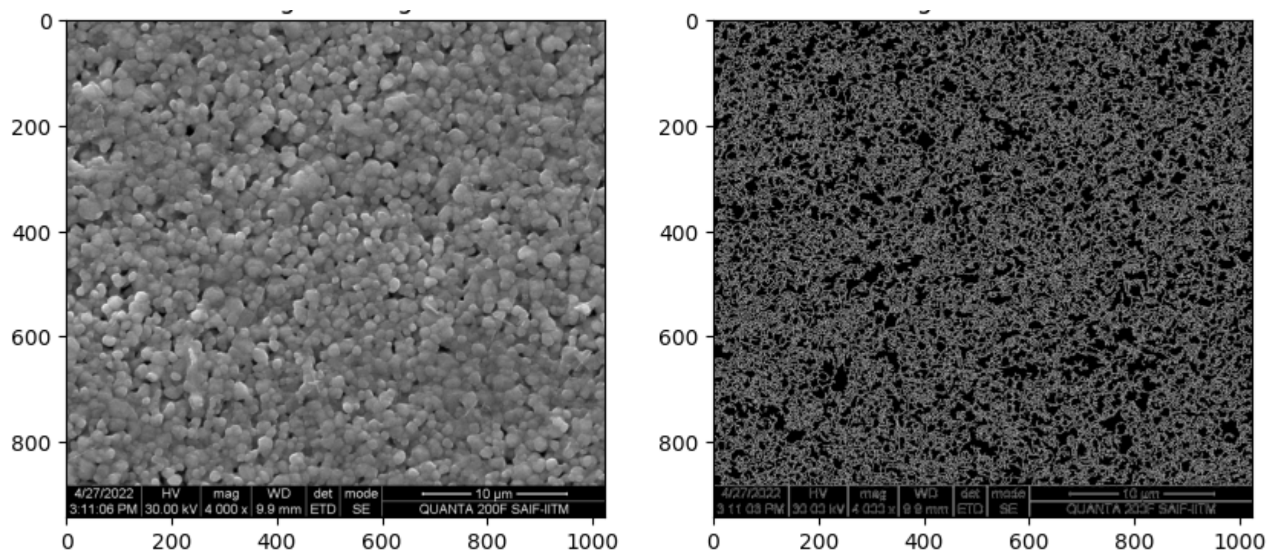


fig(4)

3D Scatter Plot and Texture Analysis

v.Advanced Image Processing :

This process's second phase includes many challenging procedures. Otsu (1979) pioneered canny edge detection, which gives a unique view into visual characteristics. Particle composition may be extensively examined with the use of GLCM texture analysis (Seah and Wang, 1998).



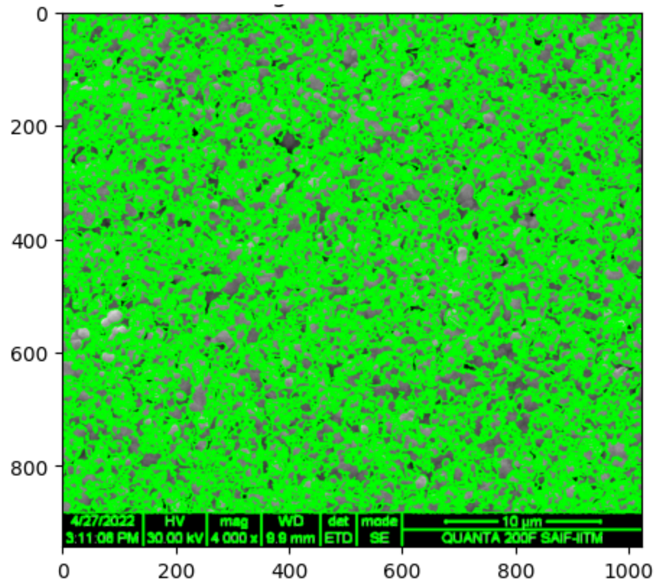
fig(5)

Original Image vs Edge Detected Image

vi.Contour Analysis and Feature Extraction:

Drawing and contour detection are integrated in contour analysis on edge-detected pictures. The principles of object identification and contour-based analysis put forward by Sciaini and Fritsch (2019) and van der Walt et al. (2011) served as the basis for this stage.

Using texture analysis based on GLCM, Seah and Wang's (1998) texture segmentation work is applied to recover the attributes of each contour area.



fig(6)
Contour Analysis Image

Applications

The proposed auto-correlation-based grain size analysis method holds significant promise for diverse applications in various scientific and industrial fields. The ability to automate grain size measurement and assess particle asymmetry presents a valuable tool for researchers and professionals alike. Here, we explore potential applications across different domains:

1. Materials science and engineering:

Quality Control in Manufacturing: The method can be applied to assess the grain size of materials during production, ensuring adherence to quality standards. It provides a quick and efficient way to monitor and control the manufacturing process for improved material properties.
Structural Analysis: Understanding the grain size is crucial for optimizing the mechanical and thermal properties of materials. The proposed technique can contribute to structural analysis, aiding in the design and development of advanced materials.

2. Nanotechnology and Nano materials:

Particle Characterization: In the field of nanotechnology, where precise particle analysis is essential, the auto-correlation method can be employed to characterize nanoparticles. This is particularly relevant for applications in nanomaterial research, where the size of particles significantly influences their properties.

3. Energy Storage Devices:

Optimizing Electrode Materials: For energy storage devices such as batteries and capacitors, understanding the grain size of electrode materials is crucial. The proposed method can contribute to optimizing these materials for enhanced energy storage and conversion efficiency.

4. Environmental Monitoring:

Particle Analysis in Air and Water Samples: The auto-correlation technique can be adapted for environmental monitoring by analyzing particles in air and water samples. This application is relevant for studying pollutants, particulate matter, and other environmental contaminants.

5. Biomedical Research:

Cellular and Tissue Studies: In biomedical research, where understanding cellular structures is vital, the proposed method can be applied to analyze the size and asymmetry of biological particles. This has potential applications in studying cell morphology and tissue characteristics.

6. Advanced Manufacturing:

Powder Metallurgy: Industries employing powder metallurgy can benefit from the automated grain size analysis. This method ensures the quality of powdered materials

used in manufacturing processes, contributing to the production of high-performance components.
Additive Manufacturing: The method can be applied in additive manufacturing processes to assess the grain size of printed materials, ensuring the structural integrity of 3D-printed objects.

7. Geological and Earth Sciences:

Mineralogical Studies: The auto-correlation method can find applications in geological studies by aiding in the characterization of mineral grains. This is valuable for understanding geological formations and exploring mineral resources.

8. Pharmaceutical and Chemical Industries:

Particle Size Analysis in Pharmaceuticals: The proposed technique can be used in pharmaceutical and chemical industries to analyze the particle size of drug formulations. This ensures the consistency and quality of pharmaceutical products.

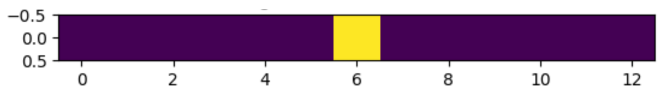
9. Educational and Research Institutions:

Teaching and Research: The method can be incorporated into educational curricula for materials science, physics, and engineering disciplines. It offers a hands-on approach to understanding particle size analysis, making it a valuable tool for teaching and research in academic institutions.

Result & Discussion

A. Particle Characterization:

The findings indicate that the recommended approach of characterizing particles is successful. Particle visibility is improved throughout the image processing pipeline, allowing more perfect segmentation. The size distribution patterns are more easily visible when particle sizes are displayed in a three-dimensional scatter plot.

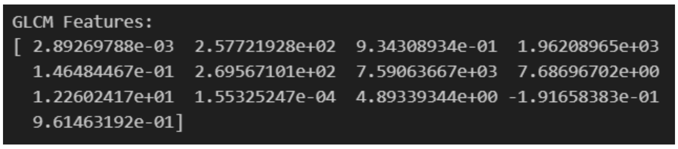


fig(7)

Clustered Regions Based On Texture Features

B. Texture Analysis:

Texture analysis delivers trustworthy information on particle composition by applying GLCM features. Seah and Wang (1998) revealed that this strategy boosts our capacity to discern between distinct particles based on their textural properties. GLCM-based KMeans clustering is used to separate particular portions of the picture in order to detect plausible heterogeneities.



```
GLCM Features:
[ 2.89269788e-03  2.57721928e+02  9.34308934e-01  1.96208965e+03
  1.46484467e-01  2.69567101e+02  7.59063667e+03  7.68696702e+00
  1.22602417e+01  1.55325247e-04  4.89339344e+00 -1.91658383e-01
  9.61463192e-01]
```

fig(8)

Output displaying GLCM Features

C. Contour Analysis:

Sciaini and Fritsch's morphological image processing theories are used to identify and create contours on edge-detected pictures (2019). For every contour area, texture analysis is included to the feature extraction process, enabling a deeper understanding of the spatial structure of textural data.

```
Region Shape: (1, 1), Non-Zero Pixels: 255
Error computing haralick features: mahotas.haralick_features: the input is empty. Cannot compute features!
This can happen if you are using `ignore_zeros`
Region Shape: (1, 1), Non-Zero Pixels: 255
Error computing haralick features: mahotas.haralick_features: the input is empty. Cannot compute features!
This can happen if you are using `ignore_zeros`
Region Shape: (1, 1), Non-Zero Pixels: 255
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This can happen if you are using `ignore_zeros`
Region Shape: (1, 2), Non-Zero Pixels: 510
Error computing haralick features: mahotas.haralick_features: the input is empty. Cannot compute features!
This can happen if you are using `ignore_zeros`
Region Shape: (1, 1), Non-Zero Pixels: 255
Error computing haralick features: mahotas.haralick_features: the input is empty. Cannot compute features!
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Region Shape: (1, 1), Non-Zero Pixels: 255
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Region Shape: (1, 1), Non-Zero Pixels: 255
Error computing haralick features: mahotas.haralick_features: the input is empty. Cannot compute features!
This can happen if you are using `ignore_zeros`
Region Shape: (1, 2), Non-Zero Pixels: 510
...
Region Shape: (27, 68), Non-Zero Pixels: 121380
Region Shape: (25, 22), Non-Zero Pixels: 36210
Region Shape: (38, 22), Non-Zero Pixels: 45135
Region Shape: (7, 6), Non-Zero Pixels: 4335
```

fig(9)

Output displaying texture features for each contour region

D. Quantitative Analysis:

By displaying a violin plot of the particle diameters and the mean particle diameter, quantitative analysis gives visual insights. The inquiry is built upon by the use of more contemporary technologies, such as edge detection and GLCM-based clustering.

```
Mean Diameter of Particles: 59.917178957294134 (pixels)
Sorted Particle Diameters: [ 13.83990574  14.45306015  14.77899456  15.22924042  15.23174667
  15.44304466  15.52437496  15.81158829  15.85589886  15.87128448
  16.1590023   16.17395782  16.41689873  16.6496048   17.20485115
  17.26287651  17.26287651  17.27584839  17.49305534  17.49305534
  17.51092148  17.69200706  17.82909966  17.90940475  18.05908585
  18.50143242  18.78849411  19.03969193  19.10085678  19.10517311
  19.10517311  19.24655151  19.31678391  19.31863594  19.41668892
  19.41668892  19.52396011  19.64708328  19.65820694  19.83530045
  20.09995079  20.09995079  20.12481117  20.22394943  20.46699715
  20.59146118  20.59353828  20.81035423  21.0438633   21.09522247
  21.10778809  21.26049232  21.40113449  21.75422096  22.02291489
  22.04895782  22.10722351  22.12602043  22.13049889  22.20380402
  22.31461716  22.3608799   22.3608799   22.47240448  22.71713638
  22.80370903  23.08699226  23.4095993   23.47221184  23.60104752
  23.60104752  23.85347557  23.94628716  24.04183006  24.04183006
  24.20763779  24.35179138  24.51550102  24.69837761  24.9458065
  25.00020027  25.06576157  25.0800724   25.0800724   25.11984634
  26.00020027  26.03109932  26.0770092   26.20997047  26.40095711
  26.41988945  26.6835289   26.90744781  27.018713    27.20314217
  27.48758125  27.65883446  27.72887611  28.08558846  28.67417145
  28.84461021  28.84461021  28.85869217  29.06908417  29.1648922
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  30.46653748  30.86502075  31.14502335  31.24119949  31.30515289
  31.93328857  32.08691788  32.25271606  32.55783844  33.24173737
...
 168.52896118 186.74671936 191.9090271  196.65725708 201.10215759
 203.00323486 262.12438965 269.02993774 269.09628296 285.61709595
 326.55877686 334.13259888 335.94448853 343.65701294 376.38796997
 621.51477051]
```

fig(10)

Output displaying Mean Diameter Of Particles

Conclusion & Future work

Ultimately, our entire approach to particle characterisation gives evidence for the efficacy of the integrated image processing and analysis methodologies. By blending old and current methodologies, we have developed a deep knowledge of the minute details included in microscope photographs of particles. A thorough examination of particle characteristics has been made practical by the effective conversion of photo formats, cropping, and pipeline processing.

The results attest to the precision and clarity of our techniques. Examples of these visual representations include the 3D scatter plot, texture analysis results, and contour analysis visualizations. Increased study and growing particle visibility have made it possible to grasp particles' sizes, orientations, and textural features in distinct dimensions.

Even as our current method gives a reasonable base, there are a lot of exciting prospects for further study. Examining machine learning algorithms for automated particle categorization is an important step. The efficacy and scalability of the study may be boosted by using state-of-the-art classification approaches to aid with particle identification and categorization.

Moreover, it is a vital step to construct our system to handle three-dimensional data. Another degree of complexity is supplied by three-dimensional imaging, and broadening our methodologies to accommodate this dimension may open up new choices for correctly exploring particle interactions and structures.

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